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# ICE CREAM

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*A TEXTBOOK FOR STUDENT AND MANUFACTURER*

BY

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# PREFACE

THIS book was written to fill a two-fold need; namely, to supply the students in the Dairy Industry with a complete and modern textbook; and to give the practical man in the commercial plant a ready reference work.

While some of the subject matter may appear technical, it is difficult to cover many of the newer phases of ice cream manufacturing without dealing with the subject in this manner. No attempt is made to cover fully some of the subjects taken up in the text. For instance, a complete book might be written on the subject of bacteriology as it applies to ice cream. However, as courses dealing exclusively with these subjects are taken concurrently by the students for whom this text is designed, the subject matter here presented is intended merely to supplement these courses.

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DAVIS, CALIFORNIA.
June 9, 1927.

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# ICE CREAM

## CHAPTER I

### THE HISTORY AND DEVELOPMENT OF THE ICE CREAM INDUSTRY

Ice cream, as it is known to-day, did not originate as a spontaneous invention. It is rather the result of a gradual evolution in the making of cold beverages and ices. The value of snow and ice in cooling wines was known in Biblical times.

Recipes for making water ices and milk ices were said to have been brought to Europe from Asia by Marco Polo, who visited Japan in the fifteenth century. Water ices are still the most popular frozen confections of the Orient, and to-day the street vendors of Eastern cities sell ice shavings moulded by hand into balls over which a dash of coloring and flavoring has been poured.

The first step in improved cooling, and with it the first real step toward our modern ice cream, was made by the Italians, who discovered that by the addition of saltpeter to snow-water, much lower temperatures were obtained than when snow alone was used. It was later learned that adding saltpeter directly to snow was just as efficient. Thereafter, water beverages were cooled by inserting the container in a dish of snow to which saltpeter had been added. Later, water was sweetened and flavored with fruit juices or other flavorings and made into water ices.

Water ices are reported to have been brought to France from Italy by Catherine de Medici, in 1550. It is also said that soon afterward they were made in Paris by Contreaux, an Italian. More definite records, however, date back to the establishment of the Café Procopé, about 1660, by another Italian, one Procopio Cultelli, or Coltelli, from Palermo. It is said that snow and ice were served in the court of Henry III of France during the hot summer months.

The name "ice cream" is of recent origin. This product was

formerly known as "cream ice" or "butter ice" because of its thick, creamy or buttery consistency. Cream ices were made in Paris in 1774. One account states that the first cream ice was served before the Duc de Chartres on a hot day in August, 1774, by his chef, who depicted the duke's coat of arms on the cream. It was also served as a sweetmeat in the form of highly colored Easter eggs, at the end of a feast given by Louis XIV.

It is accepted that cream ices were introduced into England from France by Carlo Gatti and that they were served at the court of Charles I of England. Germany is credited, however, with leading England in the making of fancy moulded ice creams.

The earliest printed record of cream ices is found in "The Experienced English Housekeeper," by Elizabeth Raffald, which was published in 1769. In 1776 a French cook, Clermont, published a book in London containing directions for the making of sweet-ices. English cook books over 150 years old give recipes for making cream ices. The early English cream ices were made of milk, sugar, eggs, arrowroot or flour, and flavoring.

Ice cream was first sold in the United States by a Mr. Hall at 76 Chatham Street, which is now Park Row, New York. It was introduced into Washington, D. C., by Mrs. Alexander Hamilton, at a dinner at which President Jackson was present. Mrs. Hamilton had become familiar with the dish in New York.

The first advertisement of ice cream appeared in a New York paper, *The Post Boy*, of June 8, 1786, and read: " Ladies and Gentlemen may be supplied with ice cream every day at the City Tavern by their humble servant Joseph Crowe."

A negro, one Jackson, who worked at the White House at the time Mrs. Hamilton, introduced ice cream to the capital, learned the recipe and later started a confectionery business. He sold ice cream readily at a dollar a quart. Though others soon imitated him, he continued to do a thriving business by maintaining a high quality of product.

The father of the wholesale ice cream industry is considered to be Jacob Fussell. Mr. Fussell was a Baltimore milk dealer in 1851 when he decided to manufacture ice cream in order to use up his surplus cream. He sold the ice cream at 60 cents a quart. Mr. Fussell soon found the manufacture of ice cream more profitable than the handling of milk, and therefore devoted his entire plant to the making of the new product. In 1852 and 1853 he tried making ice cream in the country, but the difficulties encountered there more than offset the gain made by having a cheaper source of raw materials. The country-plant idea was then abandoned. In 1862 he added another plant in Boston, and in

1864 he opened one in New York. The prevailing price then was $1.25 a quart.

The following table, showing when and where ice cream was first introduced into the various states, was prepared by Professor Mortensen and presented at the World's Dairy Congress in 1923:

TABLE I

EARLY HISTORY OF THE ICE CREAM INDUSTRY IN THE UNITED STATES

| State | Year when Ice Cream Was First Manufactured Commercially | Name of Party First Introducing Commercial Ice Cream |
|---|---|---|
| Pennsylvania *... | 1800 | Mr. Bosio, an Italian confectioner, Germantown |
| Maryland........ | 1851 | Jacob Fussell, Baltimore |
| Missouri......... | 1860 † | Perry Brazelton, St. Louis |
| Utah............ | 1860 | John R. Clauson, Salt Lake City |
| Massachusetts... | 1862 | Jacob Fussell, Boston |
| Ohio............ | 1862 | J. T. Rauslev, Cincinnati |
| New York....... | 1864 | Jacob Fussell, New York City |
| Minnesota....... | 1874 | Tinkelbaugh Ice Cream Co., Minneapolis |
| Colorado........ | 1880 | G. G. Carlson |
| Connecticut...... | 1880 | C. J. Huber, Bridgeport; or John Semon, New Haven |
| Georgia......... | 1880 † | |
| Indiana......... | 1880 | Collins Ice Cream Co., Huntington |
| Kansas.......... | 1882 | Nicholas Steffen, Wichita |
| Illinois.......... | 1885 | Bloc Bros., Chicago |
| California........ | 1886 | Carter Bros., Napa |
| Iowa............ | 1890 | F. D. Hutchinson, Sioux City |
| New Mexico..... | 1894 | J. E. Mathews, of Mathews Dairy Co., Albuquerque |
| Texas........... | 1897 | Mr. Boecleker, Dallas |
| Kentucky........ | 1898 † | |
| Arkansas........ | 1900 | Little Rock Dairy Co., Little Rock |
| North Dakota... | 1900 | Geo. Pirie Co., Fargo |
| Montana........ | 1902 | A manufacturer in Butte |
| South Dakota.... | 1903 | Ward-Owsley Co., Aberdeen |
| Nevada......... | 1908 | Harry Chism |
| Delaware........ | 1915 ‡ | Middletown Farms Dairies, Middletown |

* This was a retail plant, no ice cream being sold at wholesale.
† About.
‡ Shipped by express as far as 125 miles.

The mechanical system of refrigeration was first successfully used for commercial enterprises in 1861, though it did not find a place in the ice cream industry until after the introduction of the brine freezer. The hardening of ice cream with brine was simultaneously introduced. This system of hardening was soon almost wholly replaced by the present dry-air system, which not merely saves labor but also is the most sanitary method of hardening known up to the present time.

The homogenizer, a machine which is essential in a modern ice cream factory, was invented by August Gaulin, of Paris, France, in 1902. The United States Letters Patent were dated April 12, 1904. By the aid of this machine the texture of the ice cream has been greatly improved.

Other pieces of equipment which have added to the completeness of the ice cream factory are the Mojonnier milk tester, introduced to the trade in 1915; the Mojonnier ice cream overrun tester, introduced in 1917; the 80-quart ice cream freezer, introduced by the Creamery Package Manufacturing Company, in 1917; the Mojonnier ice cream packaging machine, which appeared in 1920; the Seal-right ice cream filling machine, 1920.

The ice cream manufacturer, in his effort along the line of expansion, has received considerable assistance from men who were not directly engaged in the ice cream business. The invention of the cornucopia, or ice cream cone, increased the sale of the product materially. The ice cream cone first made its appearance at the World's Fair in St. Louis in 1904. At that time the Hazelwood Creamery Company arranged for the exclusive right to manufacture the cone at the Lewis and Clark Exposition to be held the following year in Portland, Ore. Since then, the cone has become known in every town in the United States. The Eskimo Pie, invented by C. Nelson, Waukon, Iowa, appeared in October, 1921. This also has stimulated the demand for ice cream.

Instruction in ice cream making was offered as early as 1892 at the Pennsylvania State College. The Iowa State College was the next one to offer such instruction, but not until 1901. After that the other state colleges followed in rapid succession, until ice cream manufacture is to-day offered in thirty state colleges which give fairly thorough and scientific instruction to from 600 to 700 students annually. In addition, many of our colleges are offering short courses in ice cream making, from one to two weeks in duration; and most of them are also giving some ice cream instruction in the general and more elementary courses offered to all agricultural students.[1]

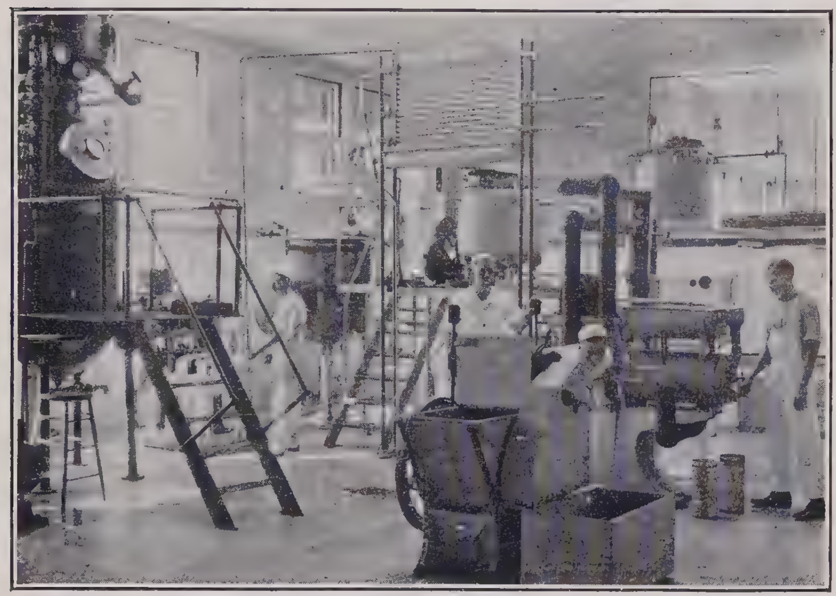
The rapid development of the ice cream industry in recent years is clearly pictured by the thoughts expressed in the discussions at the early conventions of ice cream manufacturers. Nivling[2] has examined the proceedings of practically all the conventions since the year 1907, and has discovered the following facts:

[1] M. Mortensen, before World's Dairy Congress, 1923.

[2] Nivling, S. T., before the 1925 Convention of the National Association of Ice Cream Manufacturers.

At the convention in the year 1908 the principal subjects discussed were "Standards" and "Sanitation."

In the year 1909 " Standards " was still the principal subject under consideration, because of the fact that the Department of Agriculture had endeavored to establish a 14 per cent butterfat standard. During that convention, some slight attention was given to "Gelatin."



*Courtesy Division of Dairy Industry, University of California*

Fig. 1.—The Modern College Includes a Practical Ice Cream Laboratory.

All of the subjects mentioned were continued during succeeding years; in fact, I have only mentioned those subjects which continued to receive consideration during the years following.

The question of " Standards," of course, continued through practically all of our conventions, the greatest activity with regard to this subject being during the years previous to and immediately after the year 1910.

In the year 1910, the question of "Refrigeration" and "Ice Making" were given considerable attention. About that time "Bacteria" became prominent, and cork began to be considered a better insulation than saw-dust.

In the year 1912 "Auto Trucks" were discussed as to their practicability for ice cream work. Later in the same year at the Dallas Convention, the "Homogenizer" was given prominent consideration.

In the year 1913 Mr. A. B. Gardiner, of Baltimore, Md., discussed "Ice Cream Delivery Costs." This subject was discussed rather generally, Mr. Gardiner's advice being to use a horse-drawn delivery

for the nearby territory, and the electric trucks for the distant territory. He advised against using the auto truck as it was too expensive.

Constant effort on the part of manufacturers to produce better ice cream, together with the education of the public in regard to this product and their increased confidence in it, has resulted in a remarkable growth in the consumption of ice cream.

The following table clearly pictures this growth and the present magnitude of the industry.

TABLE II

YEARLY CONSUMPTION OF ICE CREAM IN THE UNITED STATES *

| Year | Quantity, Gallons | Year | Quantity, Gallons | Year | Quantity, Gallons |
|---|---|---|---|---|---|
| 1909 | 80,000,000 | 1915 | 175,224,270 | 1921 | 216,569,212 |
| 1910 | 95,450,000 | 1916 | 208,320,000 | 1922 | 263,520,000 |
| 1911 | 138,000,000 | 1917 | 219,385,000 | 1923 | 294,000,000 |
| 1912 | 160,000,000 | 1918 | 231,053,000 | 1924 | 285,550,000 |
| 1913 | 172,380,000 | 1919 | 248,381,975 | 1925 | 322,729,000 |
| 1914 | 163,761,000 | 1920 | 257,820,490 | 1926 | 324,665,000 |

* Source: Ice Cream Trade Journal and United States Department of Agriculture.

The increased consumption of ice cream is only partly attributable to the increasing population. The increase in the per capita consumption tells the true story of the growth of the industry.

TABLE III

PER CAPITA CONSUMPTION OF ICE CREAM IN THE UNITED STATES *

| Year | Gallons | Year | Gallons | Year | Gallons |
|---|---|---|---|---|---|
| 1910 | 1.04 | 1918 | 2.14 | 1922 | 2.43 |
| 1914 | 1.68 | 1919 | 2.49 | 1923 | 2.68 |
| 1916 | 2.08 | 1920 | 2.46 | 1924 | 2.50 |
| 1917 | 2.07 | 1921 | 2.28 | 1925 | 2.80 |
| | | | | 1926 | 2.77 |

* Source: Ice Cream Trade Journal, Vol. XXII, No. 4, p. 45.

**Modern Tendencies.**—The most recent development in the ice cream industry is the tendency toward consolidation. The year 1925 and the early part of 1926 saw some of the largest plants in the country merged

into one concern. These present corporations are so large and require so much capital that their securities are now listed on the New York Stock Exchange. A glance at the industrial history of the United States will reveal many similar examples. Not many years ago, most industries in America were in the handicraft stage. Labor was the biggest factor in most enterprises. As machinery gradually took over more and more of the functions of labor in manufacturing processes, capital assumed a more important rôle than labor. This condition, of course, did not develop in all lines of industry. There are many examples of promising small concerns that tried expansion, left the old factory, and built veritable show places, only to fail. Since the same entrepreneur ability was employed in both factories, it is evident that the increased quantity of fixed capital invested was not justified.

Economists have deduced that there is a right size or scale of production for every industry. A product that demands a proportionately large quantity of capital and very little labor should be produced in large quantities. On the other hand, small-scale production must be the rule when the grade of product demands a proportionately small quantity of capital and when the labor costs are high.

The ice cream industry is passing out of the period of small-scale production. Each year sees not only a larger capital investment in the industry but a larger investment per gallon produced.

Each year machinery plays a more important part in the manufacture of ice cream than it did the year before. Every time labor is eliminated from the process, more original capital is required. The time, no doubt, is not far distant when nearly all ice cream will be made in large quantities, demanding a proportionately large amount of capital.

It should not be inferred that the small manufacturer will be entirely eliminated. There is always room for him if he will make a better grade of product, requiring more labor. The small manufacturer, for instance, can make fancy and decorated ice cream and not have the difference in the cost of production that would be incurred in the large plant, where this phase must necessarily be a side line.

## FOOD VALUE

Ice cream has a legitimate place in our nutritional plan, as is proved by the known facts brought together in the following pages. It is true, nevertheless, that frozen food products have been regarded as confections ever since the early days when snow was used to chill beverages.

In 1906, with the passage of the Federal Act regulating the purity of foods, consideration was given to the composition of ice cream, and

certain definitions were established, although the food value of the product was not considered. The chief consideration at that time was to prevent fraud in the manufacture and sale of ice cream, to guard the monetary value to the purchaser.

Ice cream was still considered largely as a confection, even up to the critical period of the World War, when the sugar famine caused it to be placed on the luxury list. This caused consternation within the industry, and efforts were made to prove that ice cream had value as a food and should be allowed a sugar allotment. The facts presented were so strongly in favor of this view that it was freed from the ban and its manufacture permitted as a food using sugar.

The interest aroused caused a continuation of the discussion of its food value. Ice cream has been finally established as a food, without, however, losing any of its popularity as a confection. Though no one now questions its great nutritive value, the fact that it was regarded for over a century as a confection should not be ignored by those interested in the industry. It is a mistake to consider ice cream in the same category as potatoes, bread, and meat, for it is unlikely ever to reach such a point. The pleasure it gives to the sense of taste will undoubtedly continue to be the controlling factor in its consumption.

**Function of Food.**—An understanding of the important part that food plays in the human body is necessary to a clear discussion of ice cream as a food. Broadly defined, a food is that which, when taken into the body, either builds tissue or yields energy.

The chief classes of nutrients necessary to maintain the human body are: fats, carbohydrates, proteids, and mineral foods.

1. *Fats, Sugars,* and *Starches.*—These are the chief food elements that produce energy, fat, and heat in the body. Cellulose and starch are not found in milk. Sugar and fat are the most important constituents. These are found in milk in sufficient and proper quantities to supply the body.

2. *Proteids.*—These chiefly produce muscles, tendons, and hair. They are also to some extent producers of energy. Good examples of the proteid group are casein and albumin, found in milk.

3. *Mineral Foods.*—The more important of these are phosphates, chlorides, and other salts of calcium, potash, and sodium, with small quantities of iron and magnesia. These chiefly produce the bones of the body.

Milk contains calcium, iron, and phosphorus in sufficient quantities to supply the needs of a growing individual. These minerals are needed especially during the period of cell and tissue building, since the nucleus of the body cell is rich in iron and phosphorus.

The water in milk is also essential to the body. Milk contains enough water to supply the body, provided the body is at rest and no food other than milk is consumed.

**Balanced Ration.**—When the various classes of nutrients are consumed in proper proportion, the so-called "balanced ration" is attained. The miscellaneous diet of to-day furnishes all these materials, but a good diet should be made up somewhat as follows:

1. *Vegetables and Fruits.*—Twenty per cent of the diet. These are called raw or natural foods, and are relied upon to furnish minerals, flavor, bulk, and vitamins.

2. *Protein Group.*—Twenty-five per cent. This is composed of lean meats, eggs, milk and fish, which build tissue, muscles, etc. The quality of the protein has much to do with its efficiency as a body builder.

3. *Carbohydrate Group.*—Twenty-five per cent. This group is composed of cereals, grains, etc., being used chiefly to give fuel and energy.

4. *Sugars and Sugar Foods.*—Ten per cent. These furnish fuel and flavor.

5. *Fats and Oily Foods.*—Twenty per cent. These are composed of butter, fats, nuts, etc. They also are largely used for fuel and flavor.

**Nutritive Ratio.**—Definite quantities of these groups are required. Within them and the balanced ration mentioned, there is another ratio known as the " nutritive ratio " and defined as the proportion between the protein or muscle builders and the heat and energy producers. This ratio is usually given as about 1 of the former to 3.7 of the latter.

The one natural food that most nearly meets this condition is milk, and, for young mammals, this is nature's food. As development continues, other foods are required and bulk foods enter the diet. No one food proves quite sufficient for adults, though milk still holds its place as most nearly fulfilling the requirements. It carries everything except the fiber for bulk, has the proper ratio, furnishes all vitamins supposed to be essential to health, and has the minerals for the bone structure. Its position as a nutrient has been established by innumerable experiments.

**Food Value of Ice Cream Constituents.**—In discussing the nutritional worth of ice cream, it is not necessary, therefore, to dwell at length upon the milk solids, except as they will be discussed later from a vitamin standpoint.

In addition to milk solids, sugar and accessories make up the average ice cream.

Sugar, meaning cane or beet sugar, when rationally eaten, is one of the best foods for supplying energy to the human body. In fact, sugar has the highest net energy value of all carbohydrates. Every food

possesses a certain amount of potential energy, which is converted in the body to kinetic energy. The body processes (circulation, respiration, digestion, and assimilation), however, consume appreciable amounts of energy, and there must be deducted from the total caloric value of the food that which is lost in the excreta. After making the necessary deductions, there remains a certain amount of the original food energy, which is termed the net energy value of the food in question. In the case of sugar, the losses are practically *nil*, in that (1) the digestive coefficient of pure sugar is practically 100 per cent; and (2) the digestion and assimilation of the sugar call for but little effort of the body.

Of the accessories mentioned above, gelatin is the most important. Others, composed of such substances as gums, are mostly inert as food, and, as long as they are wholesome, are of negligible importance. Gelatin was formerly frowned upon, but recent research by Downey[3] of the Mellon Institute of Industrial Research, shows it has decided merit in the diet. In effect, he says that it not only has physical value in assisting in the manufacture of ice cream, but also plays a part in the digestive processes, and hence is an aid to nutrition. It assists digestion by giving the digestive juices better access, since coagulation of the casein in dense or large curds is prevented. It also causes a greater flow of both digestive and pancreatic juices. Moreover, it is a protein food, containing considerable lysine, the growth value of which has been demonstrated by McCollum.

Coloring and flavoring agents, the remaining accessories, are of minor nutritional consideration.

The Government has sanctioned the use, in foods, of certain synthetic compounds, imparting color and flavor, because it has been found that, in the amounts required for foods, they are harmless and do not by their addition in any way lower the nutritive value of the product. These compounds are not toxic, nor, in the usual amounts used, are they injurious.

**Nutritive Ratio of Ice Cream.**—To qualify as good food, ice cream should have the proper nutritive ratio, i.e., a ratio accepted for milk. Milk may have the following formula: water, 87.50 per cent; total solids, 12.50 per cent; solids making up ash, 0.80 per cent; protein (casein, albumin, etc.), 3.3 per cent; sugar, 4.80 per cent; fat, 3.60 per cent; nutritive ratio, about 1 : 3.7. In comparison, 20 per cent cream has a composition of about 27.59 per cent total solids, with 20 per cent butterfat and 7.59 per cent solids-not-fat, giving a nutritive ratio of about 1 : 16.

[3] Downey, T. B., Edible Gelatin, The Ice Cream Review, May 1924, p. 136.

High-fat ice cream, having total solids 36.20 per cent; fat, 14.50 per cent; milk solids-not-fat, 7.50 per cent; cane sugar, 14.00 per cent, by the combination of cane sugar and high fat, brings the ratio up to 1 : 17. Low-fat ice cream, having total solids 35.20 per cent; fat, 9.40 per cent; cane sugar, 14.00 per cent; milk solids-not-fat, 11.80 per cent, gives a ratio of 1 : 6.

This ratio is closer, but does not meet the conditions; either the fat must be reduced with the solids-not-fat, or the solids-not-fat must be increased with the same amount of fat. It seems that the fats might be reduced and the solids-not-fat increased. This would give a formula somewhat like this, with chance for variation as individual needs require: butterfat, 10–12 per cent; milk solids-not-fat, 11–15 per cent; cane sugar, 13–15 per cent. Within these ranges, it is possible to obtain a proper nutritive ratio. It seems, therefore, that in this respect ice cream may be rightly classified as a food of merit. It is not absolutely necessary that ice cream have a perfect nutritive ratio since it may be expected to be but one of several foods making up the diet.

## VITAMINS

Within comparatively recent years, nutrition experts have discovered that the growth-promoting value of foods depends not so much upon the various chemical compounds as upon certain substances or groups of substances which have been designated by the term "vitamins." These vitamins are still "unknown" substances, inasmuch as they have never been isolated and analyzed. Nevertheless, their action has been very carefully studied.

**Origin of the Vitamins in Milk.**—That vitamins exist in milk is beyond dispute. They are not elaborated by any original process in the cow's body, but are stored up from the leafy portions of her feed and are secreted in the milk. Investigators have shown that vitamins are more abundant in summer milk than in winter milk, and ascribe this to the greater amount of leafy food eaten by cows in summer.

**Kinds of Vitamins.**—Of the five classes of vitamins, known as A, B, C, D, and E, the first three are definitely known to exist in milk.

Fat-soluble A is especially abundant in certain fats, such as milk fat or butterfat, egg-yolk fat, and the fat of certain glands, such as the liver and kidneys. This vitamin promotes growth in young animals and prevents ophthalmia (eye trouble).[4] It is the vitamin that is least abundant in nature, and hence is the one that makes milk and its products especially valuable in the diet.

[4] Ellis and MacLeod, Vital Factors of Food, p. 72. D. Van Nostrand Co., 1922.

Water-soluble B is never associated with oils or fats of either animal or vegetable origin. It is widely distributed in nature, being abundant in milk serum and in the leafy portions of vegetation. This vitamin is termed anti-neuritic and, besides promoting growth, prevents beri-beri and similar diseases due to faulty nutrition.

Vitamin C is found in juicy fruits (especially citrus fruits) vegetables, and fresh milk, and is generally supposed to be a protection against infantile scurvy.

Cereals and other foods derived solely from seeds contain little fat-soluble A; hence, young animals cannot make proper growth upon them alone.

Vitamin D prevents rickets. Besides having anti-rachitic value, it is essential for growth and aids in calcium assimilation. An abundance of calcium, however, either in milk or as calcium phosphate, does not necessarily prevent rickets. The greatest source of vitamin D is cod-liver oil.

Vitamin E controls reproduction in animals. Its greatest known sources are lettuce and the wheat germ. The diet of the human race is such that this food factor is almost invariably included, so that it is of minor consideration here.

**Effect of Heat on Vitamins.**—In experimental work, vitamins A and B have been found to resist such heat as is usually applied in cooking or processing foods. A is destroyed above 200° C., while C is affected above 100° C.

Authorities differ somewhat regarding the effect of heat on vitamin C, but they agree quite generally that its properties are injured and partially destroyed by subjection to high temperatures in the presence of air. Even the pasteurization temperature is generally conceded to destroy C. Both A and C are believed to be impaired or destroyed as milk ages, probably by oxidation.

**Effect of Freezing on Vitamins.**—That vitamins in ice cream are not affected by freezing is the conclusion reached by Smith.[5] He says:

> Vitamin A was present in the typical samples of ice cream in such concentration that one may conclude that no noteworthy alteration in its potency is caused by pasteurizing or freezing. The vitamin B of the ice cream can be accounted for by the equivalent quantity of milk used therein. Freezing has no effect on the vitamin B in the ice cream used. The ice cream, which was made from pasteurized products, contained no significant quantity of vitamin C.

[5] Smith, A. H., Vitamins in Ice Cream, Jour. Am. Med. Assoc., Vol. 79, No. 27, p. 2221.

TABLE IV

CALORIES IN VARIOUS FOOD MATERIALS *

| Food Material, Edible Portion | Calories per Pound | Calories Average Helping |
|---|---|---|
| Avocado: | | |
| Average | 985 | 344 |
| Apple | 290 | 72 |
| Banana | 460 | 127 |
| Blackberries | 270 | 60 |
| Cantaloupe | 185 | 93 |
| Grape fruit | 300 | 139 |
| Grapes | 450 | 112 |
| Orange | 240 | 100 |
| Watermelon | 140 | 39 |
| Jam: | | |
| Blackberry | 1020 | 100 |
| Currant | 1230 | 110 |
| Strawberry | 1300 | 120 |
| Jellies: | | |
| Apple | 1090 | 100 |
| Blackberry | 1090 | 100 |
| Crabapple | 1160 | 110 |
| Mixed fruit | 1190 | 115 |
| Meat | 1000 | 350–400 |
| Butter | 3300 | 119 |
| Cheese, cheddar | 2100 | 100 |
| Cream, average | ....... | 60 |
| Milk, whole | ....... | 160 |
| Egg, boiled | ....... | 90 |
| Beans, home-baked | 900 | 250 |
| Potatoes, boiled | 425 | 145 |
| Flour | 1600 | ....... |
| Bread, white | 1200 | 100 |
| Bread, graham | 1200 | 100 |
| Cereals | 1600 | 150 |
| Rice | 1600 | 150 |
| Sugar | 1820 | ....... |
| Sandwiches: | | |
| Corned beef | 1260 | 184 |
| Ham | 1410 | 214 |
| Frankfurter | 1264 | 245 |
| Chicken | 1334 | 230 |
| Cheese | 1305 | 180 |
| Nuts: | | |
| Almonds | 3030 | 100 |
| Peanuts | 2560 | 128 |
| Walnuts | 3300 | 125 |

| Food Material, Edible Portion | Calories per Pound | Calories Average Helping |
|---|---|---|
| Ice cream: | | |
| Cone | ....... | 80–100 |
| Dish | ....... | 200–250 |
| Ice cream sodas: | | |
| Chocolate: | | |
| Chocolate ice cream | ....... | 467 |
| Vanilla ice cream | ....... | 344 |
| Fresh strawberry, vanilla ice cream | ....... | 436 |
| Vanilla, vanilla ice cream | ....... | 399 |
| Ice cream sundaes: | | |
| 1. Chocolate sauce, walnuts, chocolate ice cream | ....... | 327–516 |
| Fudge sauce, walnuts, chocolate ice cream | ....... | 412 |
| Marshmallow sauce, walnuts, chocolate ice cream | ....... | 383 |
| Marshmallow and chocolate sauce, walnuts and chocolate ice cream | ....... | 429 |
| Maple walnut sauce, chocolate ice cream | ....... | 419 |
| Strawberry sauce, chocolate ice cream | ....... | 230 |
| 2. Strawberry sundaes: | | |
| Fresh strawberry sauce | ....... | 225–406 |
| Strawberry sauce | ....... | 257 |
| Strawberry sauce and marshmallow | ....... | 412 |
| 3. Vanilla sundaes: | | |
| Fresh strawberry sauce | ....... | 334 |
| Marshmallow sauce, walnuts | ....... | 350 |
| Chocolate sauce, walnuts | ....... | 396 |
| Marshmallow sauce | ....... | 251 |
| Chocolate sauce, nuts | ....... | 371 |
| Strawberry sauce | ....... | 304 |

* Data from M. E. Jaffa, University of California.

**Caloric Value.**—Reference to a table of caloric values will show how favorably ice cream compares with other foods in its class. For example, an average serving of ice cream, or $3\frac{1}{2}$ oz., contains approximately the same caloric value as the same weight of round steak, or roast chicken, and considerably more caloric value than such fish as haddock or cod.

It may be said that calories do not provide a fair basis of comparison because recognition must be given to the following requirements: (1) the protein, carbohydrates, and fat must be in the correct proportion and in sufficient quantity; (2) certain minerals must be present; (3) the quantity and quality of protein must be considered; (4) the vitamins must be present in adequate amount.

Ice cream containing 10 per cent fat has approximately 5 per cent protein, 18 per cent carbohydrates, and 0.8 per cent minerals. As a sole article of diet, it can hardly be recommended, though for that matter neither can such foods as roast beef, cheese, or eggs. The justification for using calories as a basis of comparison is that ice cream is one food of a number that should go to make up the daily diet. When the daily diet contains a reasonable variety of foods, the various requirements as to quality and proportion of protein, carbohydrates and fats, minerals, and vitamins will be met. Under such conditions, calories do provide a fair basis of comparison.

## EFFECT OF HOMOGENIZATION

The improvement in assimilability of fats through homogenization is a disputed question. Howell[6] believes that the reduction in the size of the fat globules by homogenization is a great aid to digestion. McCollum[7] says that "common experience shows that human beings and animals have in their digestive apparatus a very efficient system for emulsifying fats, so that we can take oils or solid fats and digest them without appreciable difficulty."

[6] Howell, Luther P., Ice Cream Trade Journal, Vol. XX, No. 2, p. 60.
[7] McCollum, E. V., letter to the authors, Aug. 1926.

## CHAPTER II

# CLASSIFICATION AND SPECIALTIES

**Definition.**—Ice cream is a frozen product made with pure sweet milk, cream, skim milk, condensed milk, condensed skim milk, dried milk, dried skim-milk powder, wholesome sweet butter, pure milk fat, or any combination of such products, usually sweetened, flavored, and sometimes colored, and having a small percentage of gelatin or other colloid to act as a binder.

**Modified Classification as Suggested by Mortensen.**[1]—It is only a few years since ice cream has been given an adequate classification. Formerly, ice cream was classified simply as Philadelphia or Neapolitan, the latter supposedly made with eggs, and the former without eggs. As the ice cream industry grew and many different kinds of creams appeared on the market, a more complete classification was found necessary, for the guidance not only of the manufacturer, but of the consumer as well.

A classification, to be of any value, should be generally adopted, so that the public may be made familiar with the different varieties that may be purchased. Sooner or later, the ice cream men will adopt a universal classification. Then, if the manufacturer hopes to educate the public to the use of this classification, he should abide by it himself, and, if he must give a special or fancy name to some of his creams, it should be prefixed to one of the terms used in the classification so that these terms may become fixed in the minds of the public. The housewife is likely to order more ice cream if she is familiar with the classification and knows she may secure any one of a large variety of flavors.

In the following descriptions of the various ice creams, no attempt is made to give detailed composition, inasmuch as this subject is treated from a different angle later.

I. *Plain Ice Cream.*—Plain ice cream contains the average percentage of butterfat, and is usually flavored with vanilla or such flavors as coffee, mint, caramel, and maple.

[1] Mortensen, M., Classification of Ice Cream and Related Frozen Products, Bul. 123, Iowa State College.

II. *Fruit Ice Cream.*—Fruit ice cream contains, on an average, 1–2 per cent less butterfat than plain ice cream, and has a variable amount of fresh or preserved fruits (usually 3–8 per cent), such as strawberries, raspberries, peaches, apricots, pineapples, oranges, raisins. (See Chapter IV.)

III. *Nut Ice Cream.*—Nut ice cream, like fruit ice cream, is usually 1 or 2 per cent lower in fat than plain ice cream, and contains varying percentages (usually 1–5 per cent) of nuts, with or without other flavors. The following nuts are commonly used: walnuts, almonds, hazelnuts (see Nuts, on page 60). Note: Chocolate ice cream, in most states where a lower fat is permitted for fruit and nut ice cream, is classified as nut ice cream.

IV. *Bisque Ice Cream.*—Bisque ice cream is usually higher in fat than plain ice cream, and contains a bread product or confection, such as dried macaroons, marshmallows, or sponge cake, with or without natural flavoring.

V. *Parfait.*—Parfait is usually rich in fat, containing egg yolks, with or without nuts or fruits and other natural flavors.

VI. *Mousse.*—Mousse is a frozen whipped cream to which sugar and natural flavoring has been added. The modern tendency is to increase the total solids by adding a certain percentage of ice cream mix.

VII. *Pudding.*—Pudding is usually a high-fat ice cream, with eggs, nuts, and fruits, highly flavored or seasoned. Nesselrode, Plum, Manhattan, and Oriental are the common puddings.

VIII. *Aufait.*—This is a brick ice cream consisting of layers of one or more kinds of ice cream with solid layers of frozen fruits between.

IX. *Lacto.*—This name is given to a frozen product manufactured from slightly sour skim or slightly sour whole milk, eggs, and sugar, with or without natural flavoring.

X. *Ices.*[2]—These are frozen products made from water or sweet skim milk or whole milk and sugar, with or without eggs, fruits juices, natural flavors, or additional solids. Ices are further classified as ices, milk sherbets, frappés, punches, and soufflés. There is a tendency among manufacturers to call this type of product a sherbet only when it contains

[2] **Frozen Berries.**—On the Pacific coast particularly there is a type of frozen product, known as "frozen berries." Because of its popularity in season, a formula for Frozen Strawberries is given:

| | |
|---|---|
| 12 baskets strawberries | ½ pt. lemon juice |
| 10 lbs. sugar | Color strawberry red |
| 5 oz. gelatin | Water to make 5 gals. |

Freeze with brine on to get a yield of about 7 gals.

added milk solids, such as mix, dried skim-milk, or condensed skim, and to call it a water ice when these have been omitted. Greater confusion exists in the industry in the differentiation of plain ices and sherbets than in that of any other frozen products. No universal practice exists at this time.

*Classification of Ices.*—The common varieties of ices are briefly defined in the following paragraphs:

*I. Sherbet.*—An ice made from water, with the addition of milk or skim-milk solids, stabilizer, sugar, with or without egg albumin, and natural flavoring, frozen to the consistency of ice cream.

*II. Plain Ice.*—An ice made from water, sugar, with or without egg albumin, stabilizer, and natural flavoring, frozen to the consistency of ice cream. According to the present formulæ, plain ice and sherbets are usually frozen to yield from 25–35 per cent overrun.

*III. Frappé.*—An ice consisting of water, sugar, and natural flavoring served in a semi-frozen consistency.

*IV. Punch.*—An ice flavored with liquors, or highly flavored with fruit juices or spices. Punches should be made the day they are to be served. At the time of serving, they should be of the same consistency as when drawn from the freezer. Imitation flavors of most liquors suitable for making punches may be purchased from supply houses.

*V. Soufflé.*—An ice made from water, eggs, sugar, and flavoring material. It differs from ice mainly in that it contains whole eggs.

**Formulæ.**—In giving the formulæ, no attempt is made to discuss the preparation or ingredients of the mix itself, since these are fully covered in another chapter. All formulæ are based upon 10 gals. of frozen product with 100 per cent yield. To use these formulæ, add the materials given below to 45 lbs. of mix.

### I. Plain Ice Cream.[3]

1. *Vanilla Ice Cream:* (See Vanilla, page 52).

2. *Butterscotch Ice Cream:*[4] Butterscotch is prepared by bringing to a boil 24 oz. corn syrup (such as Karo), and stirring in 1 lb. whipping cream. This is boiled for three minutes, then $\frac{1}{8}$ lb. butter is added. This is cooled and added to the mix during freezing.

[3] Flavoring materials are given in quantities sufficient for 45-lbs. of 36 per cent total solids mix. If higher solids are used, proportionately greater amounts of flavoring are necessary.

[4] In all of these formulæ, unless otherwise specified, use half as much vanilla as is required for plain vanilla ice cream. The function of vanilla in such instances is to bring out the flavor in ice cream, as salt brings out the flavor in butter. Many of these flavors would be insipid without the use of small amounts of vanilla.

3. *Caramel Ice Cream:* Twelve ounces caramel, half portion of vanilla.

4. *Coffee Ice Cream:* The flavor is prepared by boiling 1 lb. good coffee with 1 lb. water, and using only the liquid. The coffee should not be boiled long enough to become bitter. Coffee ice cream is usually colored brown with caramel or coal-tar dyes.[5]

5. *Maple Ice Cream:* Two pounds maple sugar, or 2–4 oz. "Mapleine"; 2 oz. caramel, or 1 qt. of pure maple flavor without additional coloring. If imitation maple flavor is used, the product must not be called maple ice cream but "Mapleine" or some such name.

6. *Mint Ice Cream:* One pint concentrated crême de menthe syrup; color green. Inasmuch as manufacturers have not standardized the strength of syrup and flavors, the amount of flavoring may vary with different brands.

**II. Fruit Ice Cream** (see also Chapter IV on Fruit in Ice Cream).

1. *Strawberry Ice Cream:* Two quarts strawberries, usually a half portion of vanilla; color strawberry red. Two quarts of berries are sufficient to flavor, no imitation flavor should be used. It is impossble to make a good imitation strawberry flavor. The addition of such a flavor to ice cream really ruins a good flavor.

2. *Peach Ice Cream:* Six quarts crushed peaches, a half portion vanilla; color peach (gold). (Since peaches are relatively low in flavor, this unusual amount is necessary.) Some manufacturers add a few drops of imitation peach flavoring to give the ice cream a bouquet.

3. *Apricot Ice Cream:* Same as Peach.

4. *Lemon Ice Cream:* Two pints lemon juice, 1 pt. orange juice, mixed with 3 lbs. sugar. Lemon juice can never be added directly to the ice cream without being mixed with sugar, because there is so much acidity present that it would coagulate the mix. Color lemon yellow.

5. *Orange Ice Cream:* Two quarts orange juice, $1\frac{1}{2}$ pts. lemon juice, mixed with 3 lbs. sugar. Color orange.

6. *Raisin Ice Cream:* Three and one-half pounds whole seeded Muscat raisins, prepared in water. No color necessary. (See page 85.)

7. *Cherry Ice Cream:* Two quarts chopped cherries in maraschino; color cherry red.

8. *Pineapple Ice Cream:* Two quarts crushed pineapple; color light gold. The pineapple is prepared by stirring 35 lbs. sugar into one case (6 No. 10 tins) crushed pineapple until the sugar is dissolved. It should be boiled for two or three minutes before being put into cans.

[5] The various colors referred to are discussed on pp. 41–46.

9. *Fig Ice Cream:* Two quarts Calamyrna pie grade, or, if fresh, use very ripe figs, half portion vanilla; color peanut brown.

10. *Banana Ice Cream:* Two dozen large, ripe bananas, thoroughly pulped. Color gold.

**III. Nut Ice Cream.**

1. *Walnut Ice Cream:* Four pounds finely chopped walnut meats; a half portion vanilla; color light gold. Any other nut ice cream can be made by using 4 lbs. chopped nut meats. It is a good practice in preparing nuts to grind two-thirds of the nuts fine and leave one-third coarse. It takes at least thirty-six hours for ice cream appreciably to take up the flavor of nuts, and the flavor is much better after three or four days.

2. *Chocolate Ice Cream:* Add at the freezer 2 qts. chocolate syrup. (The preparation of chocolate syrup is discussed on pages 53–60.)

3. *Maplenut Ice Cream:* Add 1–3 lbs. nuts to maple (or Mapleine) ice cream. Caramel to color.

**IV.** *Bisque Ice Cream.*—A high-fat mix is preferable, although a standard mix gives good results.

1. *Marshmallow Bisque:* Five pounds marshmallows; a full portion vanilla. The marshmallows should be dried in an oven with low heat. (Do not heat too high or marshmallows will melt.) Break marshmallows into odd-sized pieces. Marshmallows should be added about one minute before drawing ice cream. They are hard at this time, but soften up in storage and are pleasingly "chewy." White marshmallows are frequently added to chocolate ice cream, the white and chocolate brown forming a pleasing contrast. Many manufacturers prefer to make their own marshmallows. This is easily done, and the following recipe is given for those who wish to do it: One pound gelatin; 10 lbs. water; 16 lbs. fine granulated sugar; 4 oz. vanilla. Soak gelatin in one-half the water; make a simple syrup of the sugar and the remaining water, and heat to 215° F. Pour over the soaked gelatin and let stand until partially cooled. Beat until mixture becomes white and thick. Pour into pans, thickly dusted with powdered sugar, having mixture 1 inch in depth. Let stand in a cool place until thoroughly chilled. Turn on a board, cut in cubes, and roll in powdered sugar. The beating may be accomplished by means of a beater such as the Hobart, if desired.

2. *Macaroon Bisque:* Four to 5 lbs. ground macaroons; a full portion vanilla. Macaroons should be thoroughly dry before being ground or they will gum up. Any other bisque can be made by using 4–5 lbs. bread products or confections.

**V. Parfait.**—The materials given below are usually added to an ice cream mix with a higher fat than stock ice cream. (These formulæ may also be used on the stock cream.)

1. *Walnut Parfait:* Yolks of 5–10 dozen eggs; 4 lbs. walnut meats; full portion vanilla; color gold. (See page 111 for preparation of egg yolks.)

2. *Coffee Parfait:* Five to 10 dozen egg yolks; extract of 1 lb. coffee; half portion vanilla; color burnt peanut brown.

3. *Maple Parfait:* Same as for maple ice cream except for the addition of the eggs and more butterfat.

4. *Tutti Frutti Parfait:* Five to 10 dozen egg yolks; 3 lbs. candied cherries or maraschino cherries; 2–3 lbs. candied assorted fruits; 3 lbs. pineapple; full portion vanilla. The stones should be removed from the assorted fruits, all of which should be ground before being added to the ice cream. The cherries and other fruits are frequently soaked in the juice of the pineapple overnight to good advantage.

**VI. Mousse.**—A mousse is made in the following manner: Whip 2 gals. 35 per cent cream and 4 lbs. sugar in the freezer. Slowly add $2\frac{1}{2}$ gals. soft ice cream as drawn from the freezer. The mixture should be whipped just long enough to mix thoroughly. Flavor and color as desired. This formula adds more solids to the cream and does not have the tendency to stratify or become grainy, as when only the cream is whipped.

**VII. Puddings.**—Puddings are the richest kind of ice cream, containing eggs, nuts, and fruits, and are very highly flavored. To 45 lbs. mix, high in fat, may be added any of the following mixtures during freezing:

1. *Nesselrode Pudding:* One pound assorted fruit; 6 lbs. maraschino cherries; 2 lbs. pineapple; 6 lbs. candied cherries; 4 lbs. raisins; 4 lbs. macaroons; 4 lbs. almonds; ground together. Five to 10 dozen egg yolks; full portion vanilla. Color gold.

2. *Manhattan Pudding:* Five to 10 dozen egg yolks; 2 qts. orange juice; 1 pt. lemon juice; 4 lbs. walnut meats; 4 lbs. pecan meats; 4 lbs. candied cherries and assorted fruits. If the latter are not available, a mixture of 2 lbs. Maraschino cherries, 1 lb. assorted fruit, and 1 lb. pineapple makes a good substitute. Full portion vanilla.

3. *Plum Pudding:* Five to 10 dozen egg yolks; 1 lb. cocoa; 4 lbs. cherries and assorted fruits; 1–2 lbs. raisins; 2 lbs. figs (dry); 1 lb. walnut meats; 3 tablespoonfuls ground cinnamon; $\frac{1}{2}$ teaspoonful ground cloves. (Spices should be stirred into the fruits before adding to the cream.) Mixtures of this kind frequently become sticky and lumpy.

It is a good plan, before adding this mixture to the freezer, to draw off ½ pt. of ice cream and stir it in with the mixture. This has a tendency to separate the ingredients so that they become better mixed in the freezer.

4. *Oriental Pudding:* One and one-half pounds Brazil nuts; 2½ lbs. dates; 1½ lbs. raisins; 1½ lbs. dry figs; ½ lb. candied figs; tablespoonful ground cinnamon; ½ teaspoonful ground cloves; full portion vanilla.

**VIII. Aufait.**—This is a brick ice cream consisting of layers of one or more kinds of ice cream between which are solid layers of frozen fruit.

1. *Fig Aufait:* This is made with three layers of cream and two layers of sliced figs. All kinds of aufaits may be made by using different fruits. Care must be taken not to make the layer of fruit too thick, since this freezes harder than ice cream and is apt to cause difficulty in cutting as well as unpalatability. In case of fruits of low sugar content, it may be necessary to boil the fruit in a simple syrup. Oval-shaped fruits should be placed the long way of the brick in order to present the best appearance when the brick is sliced.

**IX. Lacto.**[6]—This is made from skim or whole sour milk, sugar, eggs, and flavoring.

1. *Raspberry Lacto:* Six gallons starter or sour milk; 18 lbs. sugar; 24 eggs; 3 pts. lemon juice; usual amount of stabilizer; 2 qts. raspberry juice or concentrated syrup. The first four ingredients are bases for any lacto. Any other type may be made by simply changing the flavors. For instance, to make cherry lacto, add 1 qt. cherry juice to the above formula; for pineapple, 3 gals. grated pineapple; for maraschino, 3 pts. cherry juice; for grape, 2 qts. grape juice. In the preparation of this mix, the sugar is dissolved in the starter, the eggs are separated, the whites and yolks beaten separately, and then added after the mix is in the freezer. Lacto, as a rule, is not frozen very hard, and is supposed to be somewhat soft with fairly low yield.

**X. Ices.**—Ices and sherbets have been manufactured for years. Satisfactory formulæ have not always been available. In view of the fact that sugar smooths up the ice, the tendency has been to increase the sugar to a point where it remains in the ice in a partially unfrozen condition. During the holding period it then concentrates and settles, collecting in the bottom in the form of syrup. In the trade, this is often referred to as "bleeding." Certain colloids have been used, with varying degrees of success, in preventing this "bleeding." Much of the

[6] Mortensen, M., Bul. 123, Iowa Experiment Station, Ames, Iowa.

trouble came as a result of excessive yield for the total solids of the ice. This excessive yield was due mostly to the large percentage of gelatin used in an effort to prevent " bleeding " and yet to retain sufficient smoothness during the ordinary time required for marketing. Dahlberg[7] reports the results of using various gums in conjunction with gelatin. He found that low-grade gums used with gelatin greatly reduced stabilization because of the precipitation of one by the other. This was not the case when high-grade India gum or gum tragacanth was used with gelatin. Low-grade gum prevents the incorporation of the desired amount of air. Dahlberg reports the use of agar and states that in concentrations of approximately .2 of 1 per cent it gave all the desirable action of gelatin. In some work by the authors, agar alone gave a more brittle product than gelatin. When used in ice cream, the mix whipped readily to the desired yield, but gave a body more brittle than that obtained when gelatin was used.

Dahlberg found agar alone in an ice difficult to whip, but, by the addition of gum tragacanth or high-grade India gum, he easily obtained the desired yield.

When the above colloids were used, tnere developed under certain conditions a hardening of the top of the ice. This condition is often referred to in the trade as "petrified ice." Dahlberg says it is caused by crystallization of sucrose from the supersaturated solution, accompanied by the formation of ice crystals. The formation of this hard layer can be prevented by the proper use of corn sugar, by substituting a part of the sweetness with this sugar to the extent of 20 per cent of the sucrose. With this combination, the saturation point is depressed to $-4°$ F. on account of the increased solubility. As the sugar is increased, the ice becomes softer, all other factors remaining constant. Since a certain total percentage of sugar is necessary (27–32 per cent), a certain percentage of yield must be maintained (25–35 per cent). This will dip nicely at 10° F.

Many manufacturers build an ice as they do ice cream, that is, on a solids basis, the suggested formula being as follows:

**I. Water Ice**

| | |
|---|---|
| Sucrose (beet or cane sugar) . . . | 21.0 per cent |
| Corn sugar . . . . . . . . . . | 7.0 per cent |
| Gum tragacanth[8] . . . . . . . . . . . | .20 to .40 per cent |
| Gelatin[9] . . . . . . . . . . . . . . . . . . . | .28 per cent |

[7] Dahlberg, A. C., Cornell Bul. 536.

[8] In the place of gum tragacanth, 0.7 per cent of a stabilizer such as Textor may be used.

[9] A good grade of gelatin should be used.

12–14 oz. (depending on kind and amount of fruit used) of 50 per cent citric acid solution. The balance should consist of fruits, flavor, color, and water to make 100 lbs. Lemon juice contains an average of 6 per cent of citric acid. Therefore it would require approximately 6½ pts. to replace the citric acid solution above.

It was mentioned previously that the authors differentiate between an ice and a sherbet in that an ice contains no dairy products, while a sherbet does.

An ice may consist of:

| | |
|---|---|
| 21.0 per cent Sucrose | or 21.0 per cent beet or cane sugar |
| 7.0 per cent "Staple-ice" | 7.0 per cent corn sugar |
| 52.0 per cent water | .2 per cent agar |
| 20.0 per cent fruit | .4 per cent gum tragacanth |
| | 71.4 lbs. water, fruit, fruit acid, flavor, and color |
| Total | 100.0 lbs. |

Agar should be ground and of good grade and should be stored in a dry place. Gum tragacanth is better ground. The agar should be added to 50 times its weight of water. The water should be brought to a boil and the colloid slowly added, with continual stirring, this mixture continuing to boil for five minutes. The gum, if thoroughly mixed with sugar, will not ball up and should be added directly to the mix. The agar should be added hot to the mix; the acids, fruits, and fruit juices, after adding the colloids. This mix will weigh approximately 9.5 lbs. to the gallon.

**II. Sherbet.**—This may be made by the first method given above. Add 1 per cent milk solids-fat and 2 per cent milk solids-not-fat. In addition, 2 qts. of whipped egg whites for each 8 gals. of base is sometimes used. An excellent sherbet may be made from the second formula given under **I** above, by cutting the amount of gum in two, using only 0.2 per cent and adding 3–6 lbs. of milk solids. The milk solids may be added in the form of condensed skim or cream and condensed skim. Six to 7 lbs. of condensed skim gives good results. The addition of ice cream mix tends to increase the sugar to too high a percentage, since practically the maximum has been used. Twenty-five to 50 lbs. of 4 per cent milk will take the place of the condense satisfactorily, and enough fruits, acids, color, flavors, and water should be added to complete the 100 lbs. About 10 per cent more yield can be taken on a sherbet as outlined than on an ice.

Note.—0.2 lb. agar = 3.2 oz., or 90.6 grams. The same applies to gum.

In order to obtain uniform ice or sherbet, the acid in the finished product should be the same each time. A variation in the acid affects the action of the added colloids. It also affects the flavor. Uniform acidity means uniform keeping quality and uniform flavor. As different fruits contain different amounts of acid, it is necessary to know the quantity and acidity of the fruit to be added before making up the total acid of the product. Oranges vary in acidity, and even the same amount of acid cannot be added without taking into consideration the acid in each quantity of oranges added. The desired total acidity varies slightly because of individual preferences. However, in actual practice an ice containing 0.58 to 0.65 per cent total acid has been found very desirable. (See page 302.)

**III. Frappé.**—Frappé is an ice consisting of water, sugar, and natural flavoring brought to a semi-frozen consistency. Use formulæ given for sherbets, omitting egg albumin.

**IV. Punch.**—This is a plain ice, flavored with liquors or highly flavored with fruit juices and spices, usually without stabilizer. Although alcoholic beverages are not available in America, the formulæ for punches are valuable in that imitation flavors may be substituted. Furthermore, ice cream manufacturing is developing rapidly in other countries and these formulæ may be used there. Punches may be frozen to a semi-solid consistency and served that way. Frozen punches are not intended as a dessert but as a complement to the dinner, usually being served just before or with the meat course. Many ice cream manufacturers make punches and sell them in a liquid form to be used merely as a beverage.

1. *Pomona Punch:*

| | |
|---|---|
| 7½ qts. orange juice | 15 lbs. sugar |
| 7½ gals. apple cider | 5 oz. gelatin (not more), depending on grade |

2. *Cranberry Punch:*

| | |
|---|---|
| 5 gals. water | 20 egg whites |
| 20 lbs. sugar | 7 pts. cranberry jam |
| 60 oz. lemon juice | |

3. *Roman Punch:*

Same as a sherbet, as noted above, plus enough imitation rum to flavor.

4. *Cardinal Punch:*

Use 1–1½ qts. prepared port wine flavoring.

5. *Claret Punch:* Use ¾–1 qt. prepared claret flavoring.

**V. Soufflés.**—These are made from water, eggs, sugar, and natural flavoring. A soufflé differs from a sherbet mainly in that it contains the whole egg. It is frozen exactly like a sherbet.

1. *Pineapple Soufflé:* Six gallons of water or skim milk; 8 dozen eggs; 24 lbs. sugar; 2 gals. grated pineapple; 2 qts. lemon juice. This formula may be used for any soufflé.

## SPECIALTIES

The value of a special department in the ice cream plant devoted exclusively to making fancy ice cream specialties is a subject of much controversy. Some manufacturers claim that it cannot be put on a paying basis, while others are firmly convinced that it keeps the plant busier in the winter time than if only standard commercial ice cream were sold. Those firms that have been most successful in this respect have given a great deal of time to the development of the department. On the various holidays, they announce through newspaper advertisements or circulars, appropriate designs that may be purchased for the occasion. On Lincoln's Birthday, for instance, a flag may be appropriate; on St. Valentine's Day, a Cupid or individual hearts; and on Washington's Birthday, a hatchet. For Hallowe'en, there are pumpkins, ears of corn, owls, and candles. Thanksgiving Day naturally suggests individual turkeys, pumpkins, perhaps made with cranberry sherbet. Any list of individual moulds will give an idea of the extensive variety available for nearly any occasion.

Some ice cream manufacturers have even gone so far as to build up a special catering department, having their own ovens for making the cakes and confections that are used in the fancy creams. They claim that in addition to making a nice profit from this department, they get a great deal of advertising value from the specialties. The quality and individuality of this sort of work is sure to add a certain prestige to the manufacturing firm.

Ice cream decorating is an art introduced by the German bakers. Demonstrations are really the only effective means of teaching the various phases of this work. Nevertheless, if the student or manufacturer is interested in building up this department, practice only is needed to gain skill in the work. To be a success, however, the decorator must have a very lively imagination, else he soon runs out of designs, and interest in the catering department may lag.

There are many different types of ice cream specialties, but for convenience sake they have been divided into three groups: cakes, fancy moulds, and individuals. The equipment for making these things

on a small scale is very inexpensive, the largest item in the cost of production being the amount of hand labor necessary.

**Method of Making Cakes.**—A small hole is punched in the center of an ordinary cake pan to facilitate the emptying of the pan. A small

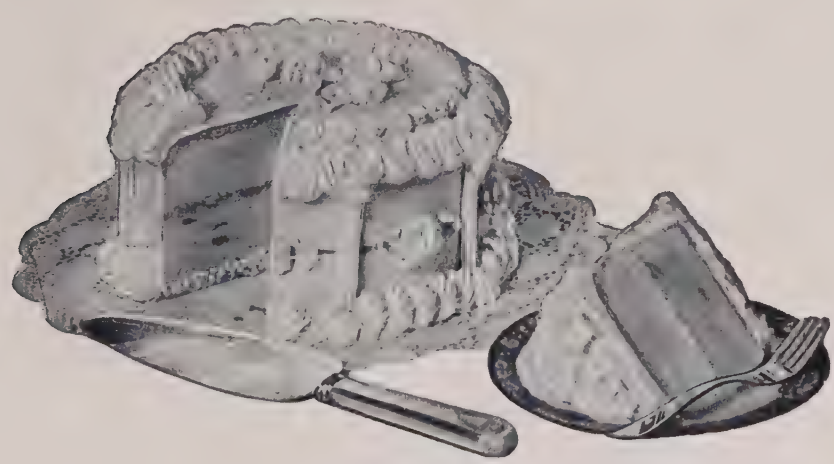
*Courtesy Crescent Creamery Company*

FIG. 2.—An Attractive Way to Present Ice Cream Individuals in an Illustrated Booklet.

piece of parchment paper is placed over the hole and the pan is filled with ice cream in a manner similar to that employed in filling brick pans. After hardening, the layers are loosened by immersing the bottom part of the pan in cold water. If a three-layer cake is to be made, the

layers are stacked one on top of the other in such a way as to bring out the contrast in colors and flavors. Sometimes a sponge cake is substituted for the middle layer of ice cream. If the ice cream layers are

FIG. 3.—Many Combinations Can Be Worked Out by Placing Individual Molds on Decorated Cakes.



*Courtesy Crescent Creamery Company*

FIG. 4.—Sponge Cake and Ice Cream.

hard and the sponge cake is well made, there is no danger of the cake's becoming soggy. Precaution should be taken not to have the sponge cake too dry, since there is little possibility of its absorbing moisture

from the frozen cream. Two- or three-layer cakes may be made in one deep pan in a manner similar to that in which three-layer bricks are made; that is, one layer is run into the pan and allowed to harden

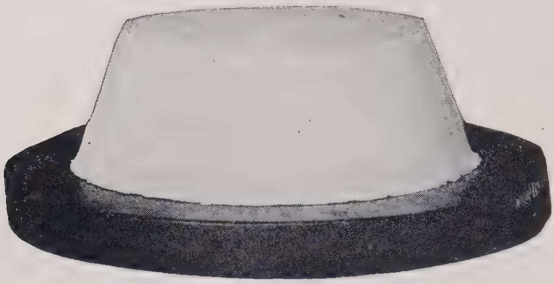


FIG. 5.—Layer Cake Covered with Whipped Cream Ready for Decorating.

before the next layer is put in. A saving of time is effected here if the inside of the pan is lined with whipped cream before the ice cream is added. When such a cake is removed from the pan, it is already smoothly covered and ready for decorating.

**Decorating.**—Decorating the cake may be greatly facilitated by using a small turntable, which can be made by boring a hole through a round board and fastening it loosely to a block so that it turns easily. The three layers should now be covered with a thin coating of whipped

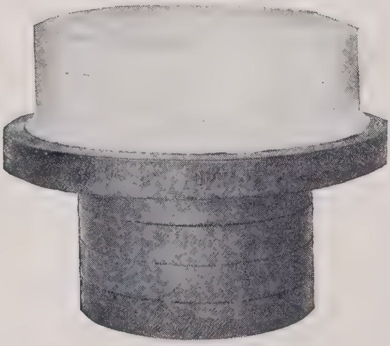


FIG. 6.—Cake on Convenient Turntable Stand Ready for Decoration.

cream, a spatula being used for this purpose. Care should be taken, however, not to use too much whipped cream, for, besides being expensive, it becomes more or less grainy when frozen. Some catering departments do not cover the entire cake with the cream, believing that the layers should show through the decoration. The cake is now ready to be decorated.

Whipped cream is used almost entirely for this work. A 40–45 per

cent cream, which has been aged for at least forty-eight hours, gives the best result. Although a lighter cream may be whipped, it does not stand up as well. Cream whips best at a temperature of 45° F. Although sugar, added either before or after whipping, decreases the whipping quality, a small amount is necessary for flavoring. Vanilla, which should also be added for the same purpose, has no effect on the whipping quality. Viscogen,[9] when properly used, increases the whipping quality of raw or pasteurized whipping cream and does not affect its flavor. Care should be taken not to whip the cream too long. If it becomes too fluffy it does not work well in the decorating tube, and if it becomes buttery it is not satisfactory for decorating purposes.

The decorating tube is a cornucopia of parchment paper (an ice cream brick wrapper is about the right size) from which the point has been clipped with a pair of scissors and the desired tube dropped into the clipped end so that it projects slightly. Figure 7 will familiarize the student with the common types of decorating tubes. The whipping

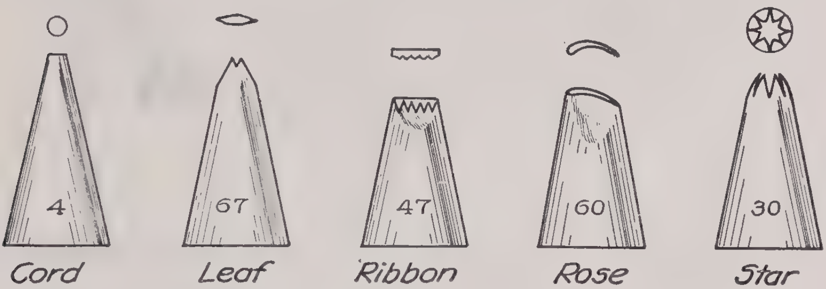



FIG. 7.—Common Decorating Tubes.

cream is placed within the parchment cone and the top end folded up so that the cream may be forced out through the tube. Practice enables the student to make a cone that may be held and squeezed with one hand.

Sometimes it is desirable to use two colors in the same tube, in which case one side is filled with one color of cream and the other side with another (use a spatula). As the cream is squeezed from the tube, a two-colored effect is obtained. The whipped cream is easily colored with a small amount of the liquid colors ordinarily used in ice cream. The decorating work is expedited if the various tubes that are to be used are filled at the same time so that the work does not have to be stopped after it has been begun. Speed in the work is particularly important if the decorating is being done in a warm room, because, if the cake melts even slightly, the cream slides off.

[10] U. S. D. A., Bul. 1075.

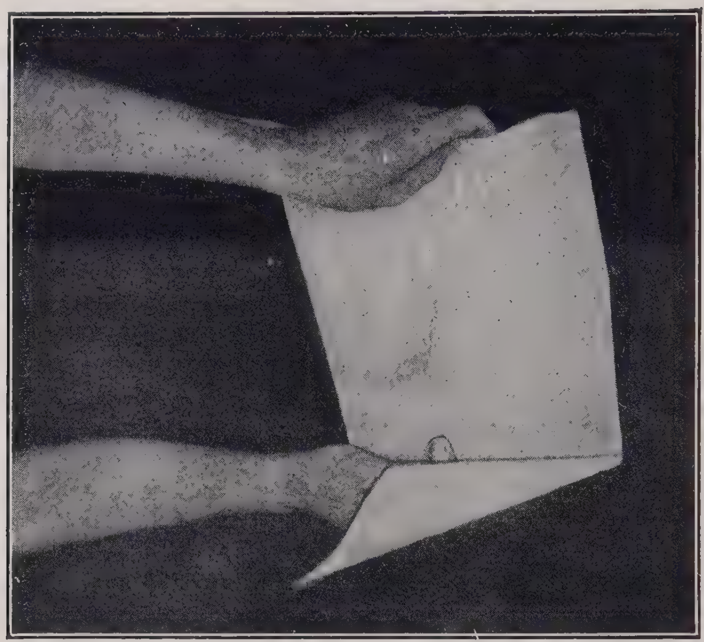


FIG. 8.—The First Step in Making the Parchment Decorating Bag.

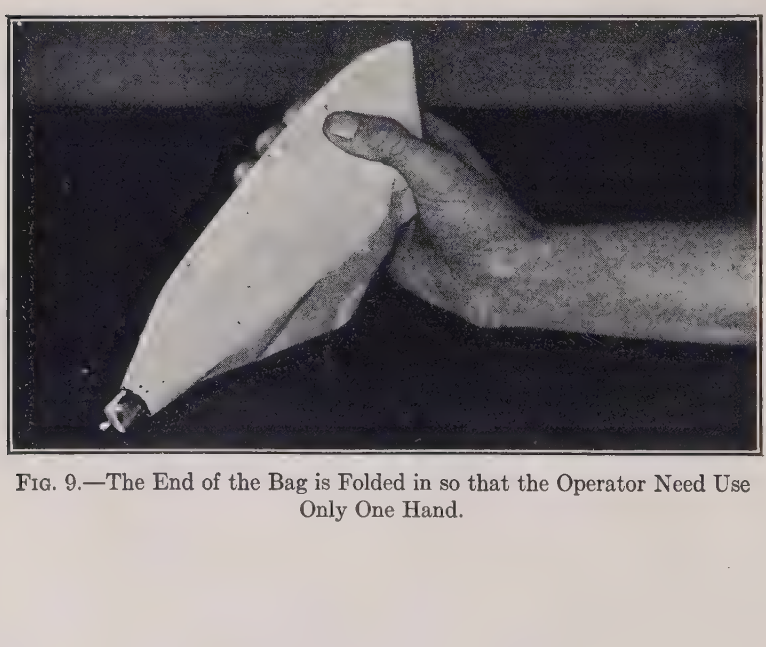


FIG. 9.—The End of the Bag is Folded in so that the Operator Need Use Only One Hand.

There are many and various designs that may be used in decorating the cake. The conventional designs, all in white, which may be seen in most bakery windows, do not make as attractive an appearance as a floral design in colors. Many designs in colors may be found in the German publication "Modeko," by A. Heckmann. Above all things, the cake must not be overdecorated. If the sides and top of the cake are decorated by means of the star tube, with uncolored whipped cream, a small bunch of roses or violets put on the top makes a very pleasing

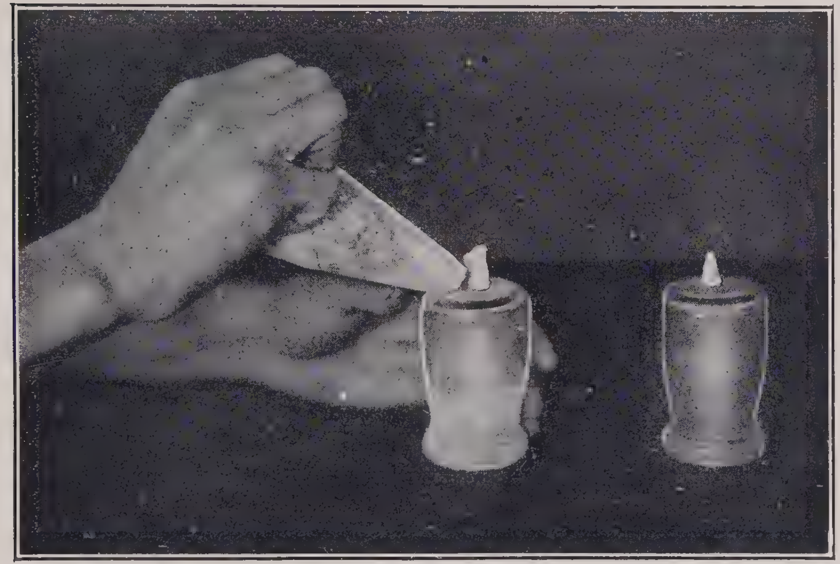


Fig. 10.—The Conical Shape on the Bottle on the Right Forms the Base for the Rose Petals.

effect, while the simplicity of the design cuts down the amount of hand labor. With a little practice in using the decorating tubes, enough skill can be acquired to make practically any design. The following are merely suggestions: bunches of grapes, violets, pansies, and sweet peas, and fraternal and national emblems.

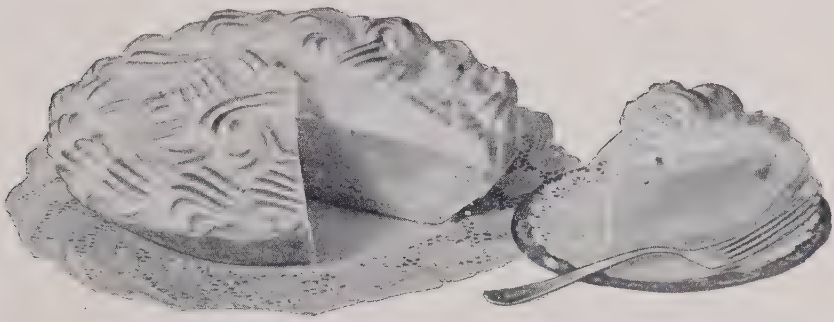
**Whipped Cream Flowers.**—Making flowers with the decorating tube is relatively simple, but it is difficult to describe. The simplest method of making a rose is as follows: A small cone of whipped cream, about ½ inch high, is placed on the inverted end of a half-pint milk bottle. This is then stored in the cold room until hard, when it is used as a base around which to build the rose. Pink or yellow whipped cream in a rose tube are used for this work. About one-half inch of cream at a time

should be squeezed against this frozen point as the bottle is revolved. Building the rose up with small squirts achieves a much more natural appearance than does squeezing the tube continuously as the bottle is turned. For the inner part of the rose, the concave side of the rose tube is made to face the frozen point. For the last few petals, the position of the tube is changed so that the concave side is out. The rose will then appear to be in full bloom. The completed flower is placed in the cold room. After it has hardened, it may be removed with a spatula and

FIG. 11.—The Rose on the Left Has Been Made with the Concave Side of the Decorating Tube Facing In. To Give the Rose a Full Bloom Effect, a Few Petals are Added with the Tube Reversed.

placed on the cake. After a little skill has been acquired, the roses may be made directly on the cake. Sweet peas and violets are easily made with a rose tube by holding the point of the rose tube in a vertical position and, while squeezing out the cream, making two inverted U movements on the same place. The U's are then covered with green sepals, the leaf tube being used. A homely but efficient way of learning to make these various flowers is to practice on pieces of cardboard, using mashed potatoes in place of whipped cream.

**Ice Cream Pie.**—Many calls are made for decorated ice cream in some form smaller than a cake. A pie may be suitable in such a case. This is made by decorating one layer of ice cream which has been hardened in a pie plate.



*Courtesy Crescent Creamery Company*

Fig. 12.—Ice Cream Pie with Meringue Topping. The Meringue Can Be Sprayed to Give the Effect of Baking.

**Individual Moulds.**—There is an individual mould for nearly every occasion. Before being filled, the moulds should be opened and placed on salt and ice so that they are thoroughly chilled before the ice cream strikes them. Ice cream placed in a warm mould melts and causes iciness. Frozen ice cream that has been resoftened comes out of the moulds

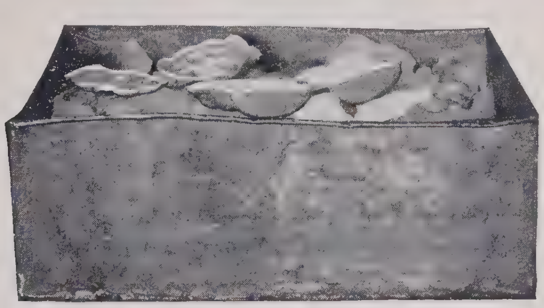


Fig. 13.—The Moulds Should Be Chilled before Filling.

better than ice cream fresh from the freezer. Forcing the softened ice cream from a parchment-filled cornucopia directly into the crevices is the most sanitary method of filling the moulds, although in practice this plan gives way to a spoon and pressure of the hand. When both halves of the mould have been filled, they are closed, and, if speed is desired, they are placed directly in an ice-and-salt mixture, since they will harden more quickly in this way than when placed on the shelves in the

hardening room. When the cream is frozen, the mould is dipped into cold water and the two halves pried apart.

**Coloring Moulds.**—The moulds really should be colored to give a like-like appearance. This may be done by painting them with liquid colors, or, when solid colors are desired, by dipping them into a weak solution of color that has been previously chilled. Spraying the dye on with a small atomizer is another satisfactory method. Some very

*Courtesy DeHaven Ice Cream Company*

Fig. 14.—As the Fancy Ice Cream Business Develops, a Large Number of Individual Moulds Will Be Required.

pretty work can be done in this manner. Furthermore, it eliminates all possibility of a small ice coating. Practice soon enables the operator to become so versatile that he can quickly do any sort of coloring work, from making lines and dots to putting a life-like "blush" on a peach. The work is facilitated if a number of interchangeable bottles are provided for the various-colored dyes.

Some decorators color the cream before filling the mould. Then, if a "corn on the cob," for instance, is being made, the green should be put on the part representing the husk, and white or yellow on the part

showing the ear of corn. This method, of course, is not as speedy as tinting the finished ice cream.

Of the various moulds, the basket seems to be the most popular,

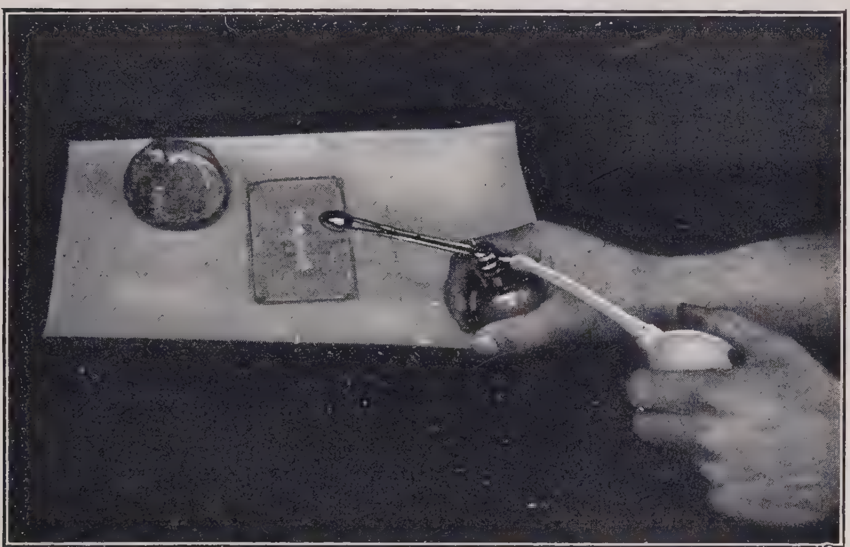


FIG. 15.—Natural Color Effects Can Be Obtained with an Atomizer.

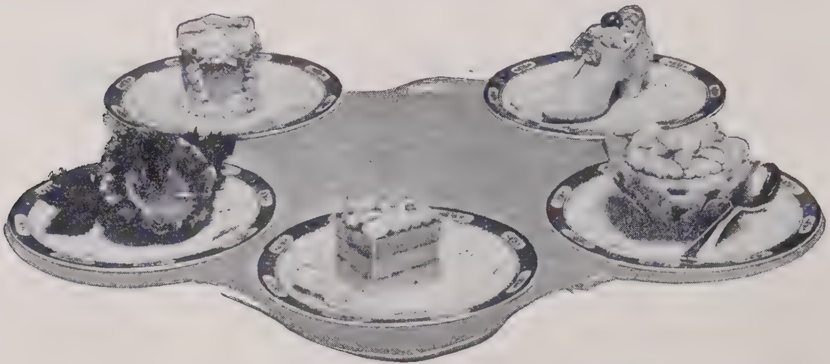
because of the possibilities it offers for decorating. The center of the basket, for instance, may be filled with whipped cream, or with a few flowers. A candy handle, which may be stuck into the cream in the

*Courtesy Hage's Ice Cream Company*

FIG. 16.—Individual Moulds Are Made Life-like with Artificial Leaves.

proper position, may be purchased from a candy manufacturer, or pure sugar-candy sticks may be heated slightly and then bent into the proper shape.

**Individuals.**—Individuals are ordinary paper soufflé cases filled with ice cream, usually fancy, the top of which is decorated in some manner.



*Courtesy Hage's Ice Cream Company*

FIG. 17.—The Variety of Individual Serving is Limited Only by the Maker's Imagination. Hage's Ice Cream Company Aptly Term Them "Frozen Dainties."

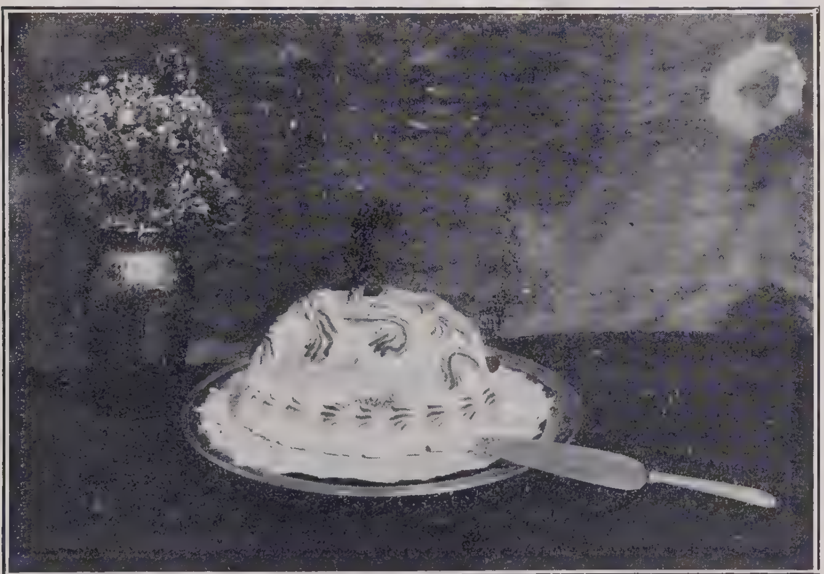
*Courtesy Crescent Creamery Company*

FIG. 18.—Center Mould—Brick and Roll.

The size of the case prohibits elaborate decorations; usually a single flower of some kind is used. The appearance is greatly improved when

they are served in decorated cases, such as those used for serving salted nuts. These cases are made by pasting or sewing Dennison crepe in various shapes on the outside of the soufflé case. Trained demonstrators are furnished by the Dennison Manufacturing Company for instruction in this work.

**Center Brick.**—One of the oldest ice cream specialties, and one that is still very popular, is the so-called center brick. This type of brick is made by filling the center mould with ice cream and hardening it. After removal from the mould, it is placed horizontally in a quart-brick pan half filled with soft cream. The pan is then completely filled. Care



*Courtesy Crescent Creamery Company*

FIG. 19.—Melon Mould of Ice Cream Covered with Meringue, Browned by Placing in a Hot Oven. This is Sometimes Known as "Baked Alaska."

should be taken not to place the center mould in cream that is too soft, as it may sink out of position. A contrast in color between the core and the outside gives the most pleasing effect.

**Dummy Moulds.**—Having an exhibit of dummy moulds on display with the various agents is an aid in securing orders for these specialties. Making these moulds is relatively simple. Paraffin ("Parawax" or "Texwax") is the best material for making the fruits, flowers, and animals. The paraffin is melted and colored the desired shade with oil-soluble colors. It is difficult to tell the shade when the wax is melted. A little of the colored paraffin should be spread on a table and allowed

to harden. The color as then shown will be like that which comes from the moulds. Most of these colors are very strong and must be used sparingly. When the melted paraffin is the right shade, it should be

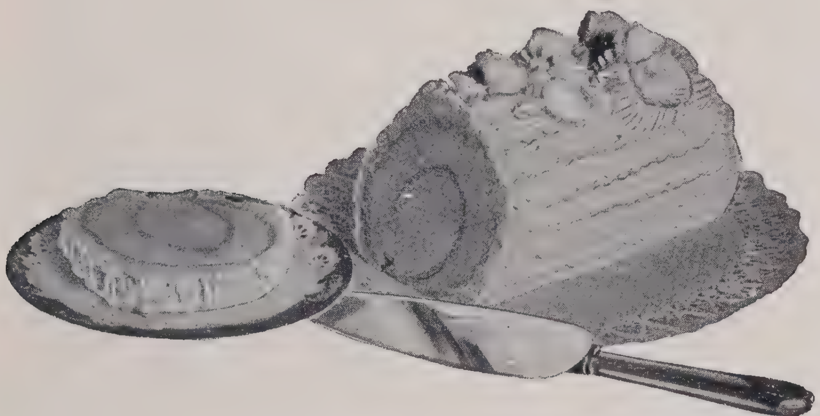
*Courtesy Crescent Creamery Company*

FIG. 20.—It's an Imposition on the Florists, but One Really Can "Say It With Ice Cream."

allowed to cool until it begins to firm. It is then ready to be put into the moulds. (The hot liquid paraffin cannot be poured into the moulds, because it shrinks when hardening, with the result that large holes are formed.) When the moulds are filled, they are placed in the cold room.

They may be easily removed when hard. The peaches and pears may be given a " blush " with a little red melted paraffin used as a paint.

Cakes, Sultana Rolls, etc., are decorated with a paste that will harden when dry. This paste is made with 6 lbs. XXXX powdered sugar, a teaspoonful of cream of tartar, and enough fresh egg whites to make a paste. This paste should be whipped until it begins to string. A machine whip greatly simplifies this task, as it is rather laborious to



*Courtesy Crescent Creamery Company*

FIG. 21.—Log Roll. Cake and Ice Cream to Imitate a Jelly Roll.

do by hand. When the paste is made, it is colored and decorated with whipped cream.

**Frozen Suckers.**—A recent introduction known as Frozen Suckers (sometimes called Popsicles), like most novelties, has proved very popular upon its introduction. Frozen suckers are made by freezing an ice or sherbet mix, colored and flavored, in small cylinders, with a stick, slightly smaller than a pencil, held in the center. The stick serves as a handle to support the frozen mass while it is eaten. A milk-bottle cap, placed on the stick before it goes into the form for freezing, keeps the whole mass, as well as the melted portion, away from the hands of the person eating the frozen sucker.

**Individual or Single-service Cups.**—Another recently popular way of putting up ice cream for the consumer is in individual cups with a small wooden spoon under the cover. The cups are filled and frozen at the plant before delivery to the retailer. Frequently, a spoonful of ice cream is removed and replaced with an equal quantity of fountain fruit or syrup.

There is real merchandizing merit in individual cups, in that they conform to the modern demand for package goods. In addition, all loss from dipping is eliminated.

*Courtesy Crescent Creamery Company*

Fig. 22.—Three-tier Log Roll, Tied with a Ribbon and Decorated with Artificial Flowers.

**Sandwiches or Slices.**—Another form of individual is the ice cream sandwich. An ordinary quart brick is cut into eight or ten slices, each of which is wrapped in waxed paper and put into a carton. Sometimes a wooden spoon is placed inside the carton.

## CHAPTER III

## COLORS AND FLAVORS

For many years the practice of coloring foods was looked upon askance by the consuming public. Better regulations governing the use of colors in foods, together with the purity of the colors themselves, have largely removed this aversion. To-day the sign in the soda fountain proclaiming the use of artificial colors and flavors receives but a casual glance.

Coloring food is an art that is not sufficiently followed in America. More thought given to the color and the appearance of food would greatly improve the American cuisine.

Even in the matter of ice cream, color plays an important part. Too much color is more undesirable than none. Only light shades should be used. Strawberry ice cream without the addition of coloring has a grayish appearance that is unappetizing. Even plain vanilla needs a little coloring, more in the winter than in the spring, to get away from a dead white appearance.

**Annatto.**—Annatto is a reddish-yellow coloring matter, derived from the pulp enclosing the seeds of the *Bixa Orellaha*, a shrub indigenous to South America and the West Indies. Two types of solutions of the coloring matter are used in the dairy industry: an oil solution used for butter color, and a weak alkali solution used for coloring cheese.

**Coloring All the Mix.**—The cheese color makes the best color for vanilla. It has the property of coloring both the casein and the fat. As a matter of fact, it is a good practice to add cheese color to all mix at the time of pasteurization. The pasteurizing and homogenizing processes thoroughly incorporate the cheese color so that 5 or 6 c.c. to 100 lbs. of mix give a natural butterfat color to the frozen product.

**Regulations.**—The rules and regulations governing the use of colors and dyes in foodstuffs are covered by the " Food Inspection Decisions " issued by the Secretary of the United States Department of Agriculture.

The laws[1] specify briefly that:

[1] Food Inspection Decisions, 76, 77, 117, 129, 159, U. S. D. A. Announcement of January 9, 1920, and U. S. D. A. Miscellaneous Circular No. 52, November, 1925.

1. Dyes are prohibited when they are used to color a food in a manner whereby damage or inferiority is concealed.

2. Only those dyes listed may be used to color foods.

3. All such dyes must bear a certification[2] of the Secretary of Agriculture that the dye has been tested by competent experts and found to be free from harmful constituents.

**The Permitted Dyes.**—

Yellow Shades:

| | | |
|---|---|---|
| 10 | (4) | Naphthol Yellow S |
| 640 | (94) | Tartrazine |
| 61 | | Yellow OB (ortho-tolueneazo-β-naphthylamine) |
| 22 | | Yellow AB (Benzeneazo-β-naphthylamine) |

Orange Shade:

| | | |
|---|---|---|
| 150 | (85) | Orange 1 |

Red Shades:

| | | |
|---|---|---|
| 184 | (107) | Amaranth |
| 80 | (56) | Ponceau 3R |
| 773 | (517) | Erythrosine |

Green Shades:

| | | |
|---|---|---|
| 670 | (435) | Light Green S F Yellowish |
| 666 | (433) | Guinea Green B |

Blue Shade:

| | | |
|---|---|---|
| 1180 | (692) | Indigotine |

The numbers in parentheses are for identification and are taken from the 1904 edition of A. G. Green's "Systematic Survey of the Organic Coloring Matters," which is a translation from the German of Schultz and Julius. The first number in each line is that of the dye as listed in the color index of 1924, published by the Society of Dyers and Colourists of England.

Tartrazine is the most commonly used of the yellow shades. It is easily soluble in water and produces a distinct lemon-yellow shade.

[2] Unless special precautions are taken in manufacturing and purifying, ordinary coal-tar dyes contain impurities which may be more or less toxic. Before dyes may be used for coloring foods a sample of each batch must be sent to the U. S. Bureau of Chemistry for analysis. If the dye meets the standard of purity set for certified dyes, then the manufacturer may take the necessary steps to have the dye certified for use in coloring food. Full directions for certification of coal-tar food colors are given in U. S. D. A. Miscellaneous Circular No. 52, November, 1925.

Yellow AB and Yellow OB are soluble in oils, while the other nine dyes are soluble in water and insoluble in oils. These two yellow colors are used to some extent for coloring butter and oleomargarine, although they have been largely displaced for this purpose by color made from annatto seed. Naphthol Yellow S gives a pure yellow tint, but because of its bitter taste it is little used.

Orange 1 is easily soluble in water and produces a good orange tint. It finds many uses in ice cream, alone or in combination with other colors. For instance, it may be used alone for coloring orange ice cream. In combination with Tartrazine, in the proportion of 1 to 9, it gives a good egg-yellow shade.

Amaranth is easily soluble in water and gives a raspberry color.

Ponceau, dissolved in water, is a reddish-orange color, and when used to color ice cream gives a bright cherry color. Some manufacturers use it to color strawberry; a better strawberry color, however, is obtained with a mixture of Ponceau and Amaranth.

Light Green S F Yellowish gives a green solution in water. It is used alone to color crême de menthe and mint-flavored ice creams.

Indigotine gives an Indigo blue color, but because of its instability is little used in water solutions. It keeps better when made into a paste with a base of glycerine.

The above coal-tar colors are known by the trade as "primaries," and all mixtures, either dry or in solution, are called "secondary" colors.

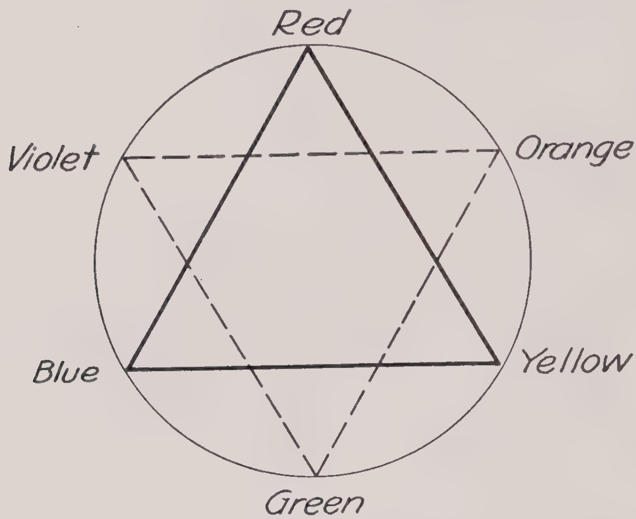
**Color Solutions.**—The manufacturer need buy only the coal-tar primaries in the powdered form and can then make up his own solutions. To buy the colors already in solution is a needless expense, for little effort is required to make the solutions. The powder is dissolved in hot, preferably distilled, water at 150–180° F. It is not necessary to boil the water. Three to 8 oz. of powder will dissolve in 1 gal. of water. An exact ratio cannot be given and accepted as infallible, since the various makes of powder vary somewhat. The manufacturer must determine for himself the amount of powder to put in solution.

Bacteria grow rapidly in solutions of these colors. The California State Department of Agriculture found the bacteria count in them to run as high as 93,000,000 per cubic centimeter. The result is marked decomposition or fermentation, accompanied by a change of color. Therefore, solutions not intended for immediate use should be preserved by the addition of some approved preservative, such as benzoate of soda. One-tenth of 1 per cent is sufficient.

The manufacturer may keep large stock solutions of the primary dyes on hand and make up smaller quantities of other colors from these.

Before large quantities are made, however, trial tests should be made with small amounts to determine the fitness of a color for a specific purpose. The solutions should be stored in glass containers away from the direct rays of the sun.

**Principles of Color Combination.**—A simple table supplies the necessary information, in most cases, for making the various shades from the coal-tar primaries. If the fundamentals of colors are understood, how-




*Source: Prof. Jackway, University of California*

Fig. 23.—The Chromatic Circle.

ever, nearly any hue may be accurately made. A knowledge of these fundamentals is almost indispenable to the clever decorator of fancy ice creams.

There are three pigmental hues which cannot be produced by any mixture with other colors, but which are themselves capable of producing, in conjunction with black and white, all other colors. These three colors, which for this reason are called the primaries, are red, yellow, and blue. Being as unlike as possible, they may, for the sake of clearness, be conceived as lying at the points of an equilateral triangle inscribed within the circumference of a circle.

Any two of the primaries can be mixed to form a third color, which partakes equally of the qualities of its constituent primaries. Thus, red and yellow yield orange; yellow and blue yield green; and blue and red yield violet. These resultant hues, which are called the secondaries, accordingly lie midway between the two primaries which unite

to form them, and directly opposite the third primary on the chromatic circle.

Instead of uniting any two of the primaries to form secondaries, or colors partaking equally of the qualities of their components, one can, of course, unite them in different proportions to form other hues partaking unequally of these qualities. Thus, red can be made dominant in a mixture of red and yellow in a degree that will produce red-orange, a color sharing equally the qualities of red and of orange. Similarly, yellow may be made dominant in such a degree as to form yellow-orange, lying midway between orange and yellow. This process can be continued indefinitely, since it is manifest that any two primaries can be united in any proportions whatever, thus producing, in theory, an infinity of hues differing by infinitesimal gradations. Most of these hues have not been named.

With the principles governing color combinations in mind, it is an easy matter to secure nearly any desired color from a mixture of the coal-tar "primaries." The following table of tested combinations may prove useful.

TABLE V

Suggestions for Color Combinations

Persian Rose
- 88 parts 517 Erythrosine
- 8 parts 94 Tartrazine
- 4 parts 107 Amaranth

Rose, Bluish
- 500 parts 517 Erythrosine
- 50 parts 107 Amaranth

Striping Red
- 10 parts 517 Erythrosine
- 30 parts 107 Amaranth
- 60 parts 56 Ponceau 3-R

Cherry Red Shade No. 1
- 68 parts 107 Amaranth
- 32 parts 85 Orange 1

Cherry Red Shade No. 2
- 100 parts 56 Ponceau 3-R

Lemon-Yellow Shade
- 100 parts 94 Tartrazine

Leaf Green
- 100 parts 435 Light Green S F Yellowish

Violet
- 88 parts 107 Amaranth
- 42 parts 692 Indigotine

Burnt Peanut Brown
- 45 parts 85 Orange 1
- 25 parts 56 Ponceau 3-R
- 30 parts 435 Light Green S F Yellowish

Orange (Yellowish)
- 50 parts 94 Tartrazine
- 50 parts 85 Orange 1

Reddish Orange No. 2
- 75 parts 56 Ponceau 3-R
- 30 parts 94 Tartrazine

Crême de Menthe Green
- 48 parts 435 Light Green S F Y
- 52 parts 94 Tartrazine

Carmine Red Shade
90 parts 517 Erythrosine
10 parts 56 Ponceau 3-R

Deep Red Shade
75 parts 56 Ponceau 3-R
25 parts 107 Amaranth

Strawberry Shade No. 1
94 parts 107 Amaranth
16 parts 56 Ponceau 3-R

Strawberry Red Shade No. 2
30 parts 107 Amaranth
70 parts 56 Ponceau 3-R

Guinea Green B 433
Similar to light green but slightly more blue in shade

Blue
95 parts 692 Indigotine
5 parts 107 Amaranth

Chocolate Brown
28 parts 692 Indigotine
20 parts 107 Amaranth
40 parts 94 Tartrazine
12 parts 85 Orange 1

Reddish Orange
90 parts 85 Orange 1
10 parts 107 Amaranth

Yellow Egg Shade
90 parts 94 Tartrazine
10 parts 85 Orange 1

Raspberry Red Shade
100 parts 107 Amaranth

Golden Yellow
75 parts 94 Tartrazine
25 parts 85 Orange 1

## VANILLA

It is generally understood and appreciated that palatability contributes in large measure to the digestibility of our food. Whenever food that is aromatic, or pleasing to the taste, enters the mouth, it automatically causes a secretion of juices, which at once begin their function of digestion. This is the phenomenon that the physiologist calls " psychic secretion."

Most of the organic compounds are tasteless in the pure form. The flavor of food products, then, except for sweetness, is due largely to minor constituents such as organic acids, esters, and essential oils. These are present in such small amounts that artificial flavoring is necessary. Vanilla and lemon are the most common flavors in general use. When the ice cream industry was in its infancy, practically all of the ice cream made was lemon-flavored. In recent years, however, vanilla has become the most popular flavor, more than 50 per cent of all ice cream manufactured being of this flavor.

Vanilla is the fruit capsule of an orchid, *Vanilla planifolia*. The capsules are filled with a transparent balsam, in which the black seeds are imbedded. It is in the balsam that the vanillin, which gives the agreeable aroma to vanilla, is produced.

The freshly gathered vanilla fruit is green and without odor and contains no free vanillin, or merely an infinitesimal quantity.[3] This is developed by subsequent treatment. The process of fermentation, or sweating, develops the free vanillin, which is formed by the splitting up of a glucoside.

Vanilla blooms in October and November, is gathered in May, June, and July, and is prepared in October and November. At the beginning of November, the first installment of the new harvest arrives on the market.

*Courtesy Hudson Mfg. Co.*

FIG. 24.—Vanilla Beans During the Drying Process.

The most important operation in handling the vanilla beans is that of bringing them to the proper degree of dryness. When insufficiently dried they soon become mouldy; when overheated, although they keep well, they are brittle, break easily, and consequently have little commercial value. The beans are cured both naturally and with artificial heat. The "natural" method is to sweat them between folds of blankets after exposing them to the air. This process must be repeated daily for about four weeks.

The beans may be cured more quickly by exposure to artificial heat in the presence of calcium chloride. Although beans so cured are considered inferior in quality, it is claimed that they retain their aroma better.[4]

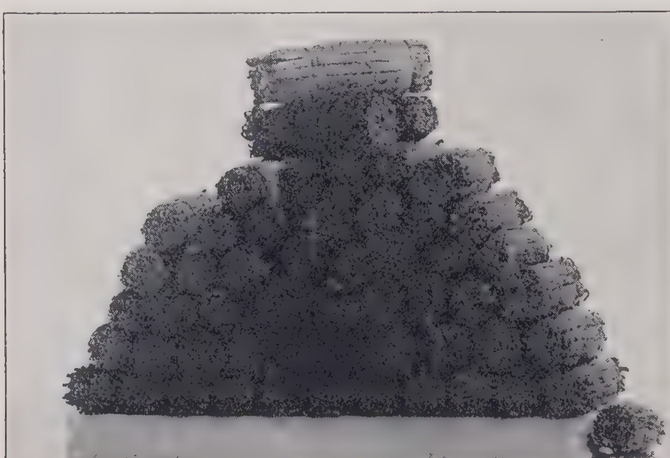
[3] Arbeiten aus dem kaiserl. Gesundheitsamtes, Vol. 15, p. 1–113. Berlin, 1899.
[4] Dr. S. Die Erntebereitung, Der Tropenflanzer, Vol. 2, pp. 24–26, 1898.

**Grades of Beans.**—There are many different grades of vanilla beans, Mexican vanilla being the most delicate. Certain valleys in Mexico

*Courtesy Hudson Mfg. Co.*

Fig. 25.—Sorting and Grading Vanilla Beans.

are the natural homes of these plants, and although they may be grown in other places they do not have the refined, delicate flavor and the



*Courtesy Hudson Mfg. Co.*

Fig. 26.—Vanilla Beans Ready for the Market.

aroma of the Mexican bean. Bourbon beans, grown on the Isle of Réunion, are next in quality, but do not have the excellence of the

Mexican bean, because the plants were removed from their native habitat to be grown on this island. They resemble the tonka bean in odor. The tonka bean is almond-shaped, with a single seed containing a great deal of coumarin. This gives a harsher vanilla flavor than that of the Mexican bean.

Cheaper varieties are those from South America, which do not bring

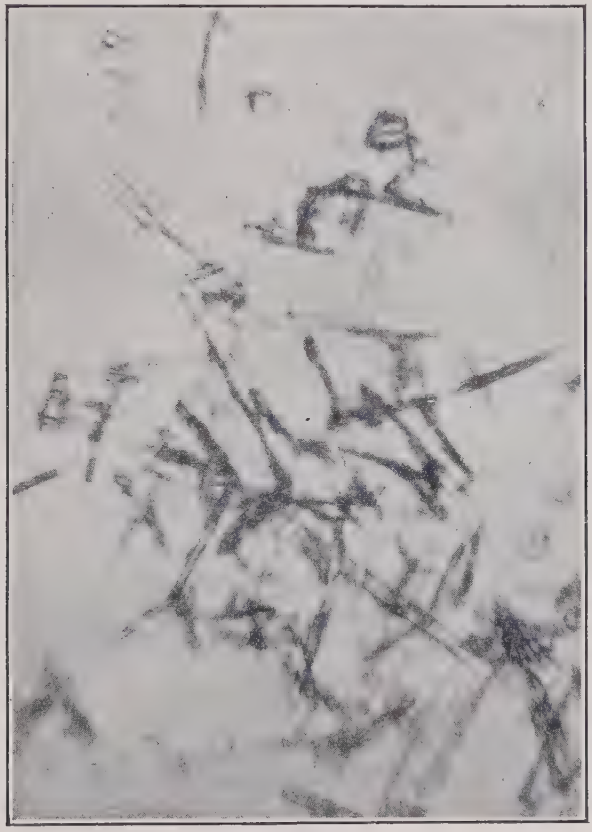


FIG. 27.—Benzoic Acid Crystals.

half the price of the Mexican beans; and the cheapest of all are the Tahiti beans and the so-called "vanillons," which are the seeds of the wild vanilla (*Vanilla pompona*). Varieties known as "splits" are also on the market. These are beans which have been allowed to ripen on the vine and which have split in curing. They are undesirable on account of their full and heavy flavor. "Mexican cuts" are undesirable seconds, chopped and mixed, composed of beans that have been poorly cured or

broken, and others that have fallen early from the vine. The market prices for the various grades of beans vary considerably. As an illustration, the best grades of Mexicans on the market (January, 1924) commanded a price of $15 a pound, while Tahitis could be bought for $3.50.

Beans that have been deprived of vanillin by extraction with alcohol are sometimes found on the market. Their color and appearance are restored by immersion in tincture of benzoin and by coating with crystals of benzoic acid to give them the appearance of the natural vanillin crystals. These two crystals can be readily distinguished under the microscope.

**Compositions of Vanilla Extract: U. S. Standards.**—Vanilla extract is the flavoring extract prepared from the Vanilla bean with or without sugar or glycerine, and contains in 100 c.c. the soluble matters from not less than 10 grams of the vanilla bean.

Vanilla bean is the dried, cured fruit of *Vanilla planifolia Andrews.*

Tonka extract is the flavoring extract prepared from tonka beans with or without sugar or glycerine, and contains not less than 0.1 per cent by weight of coumarin, extracted from the tonka bean, with the corresponding proportion of the other soluble matters thereof.

Tonka bean is the seed of *Coumarouna odorata.*

**Preparation of Extract.**—At one time, most vanilla was prepared by allowing the beans to soak in alcohol until the soluble matter had been dissolved out. Inasmuch as this process required several months, percolating is coming into practice more and more.

The U. S. Pharmacopœia method of percolation fully illustrates the principle:

Vanilla cut into small pieces and bruised, 100 grams. Sugar in coarse powder, 200 grams. Alcohol and water, each sufficient quantity to make 1000 c.c. Mix alcohol and water in the proportion of 650 c.c. of alcohol to 350 c.c. of water. Macerate the vanilla in 500 c.c. of this mixture for twelve hours, then drain off the liquid and set aside. Transfer the vanilla to a mortar, beat it with the sugar in a uniform powder, then pack it in a percolator and pour upon it the reserved liquid. When this has disappeared from the surface, gradually pour on the menstruum and continue the percolation until 1000 c.c. of tincture are obtained.

The formula of a commercial vanilla, selling in the spring of 1926 for approximately $14 a gallon, is given below:

$12\frac{1}{2}$ lbs. Bourbon beans
$12\frac{1}{2}$ lbs. Tahiti beans
$\frac{1}{2}$ gal. glycerine
$13\frac{3}{4}$ gals. alcohol
$10\frac{3}{4}$ gals. distilled water

If the manufacturer in America plans to make his own vanilla extract, he must secure a permit from the Government to obtain pure grain alcohol. This is done by filling out the Treasury Department's Form 1404 in triplicate and filing it with the Federal Prohibition Director of the State in which the plant is operating. If 15 wine gallons of alcohol or less are procured every three months, it is not necessary to file a bond.

**Adulterations.**—Adulteration of vanilla extract is usually accomplished with one or more of the following: coumarin ($C_9H_6O_2$), either

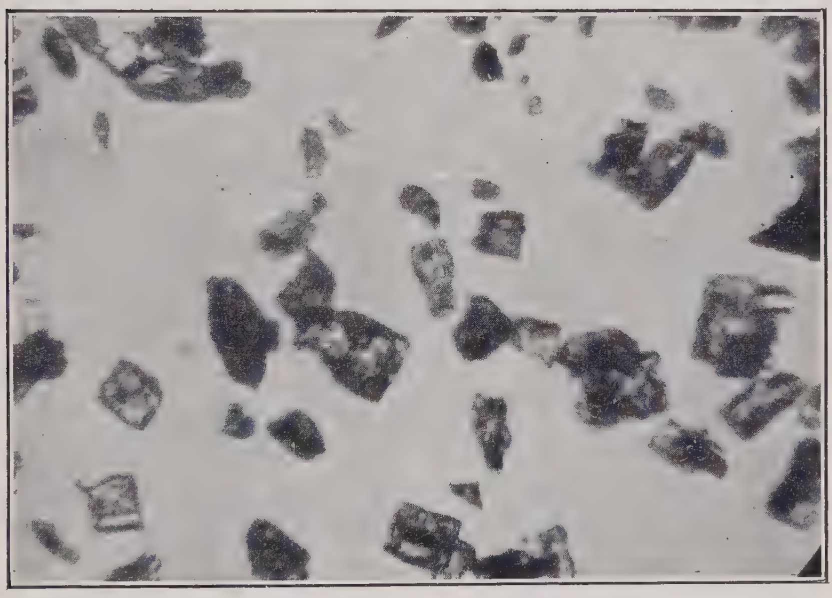


Fig. 28.—Coumarin Crystals Used to Reinforce Vanilla Extract.

extract of the tonka or prepared from chemicals; artificial vanillin ($C_8H_8O_3$) prepared from chemicals; prune juice; caramel.

Imitation vanilla flavors are usually made of a mixture of natural or artificial coumarin with chemically prepared vanillin in a weak alcohol colored with caramel. Prune juice is frequently used to give body and flavor to these imitations. These artificial preparations possess a pronounced flavor which is very gross in its nature, lacking the delicate and refined flavor of the genuine extract.

**Detection of Artificial Extract.**—Coumarin or tonka tincture in vanilla extract is usually recognizable, to a certain degree, by the odor, if one is at all familiar with these flavors. If two samples are taken, one known to be good vanilla and the other to be an artificial prepara-

tion, it is possible to distinguish between the two. The odor of coumarin is more pungent and penetrating than that of vanillin, and in mixtures it is apt to predominate over the milder and more delicate odor of vanillin. Vanilla extracts which, when untreated, are too strong to allow the taste to be determined, may be tasted by placing a few drops on lumps of sugar and tasting the flavored sugar. Weak standard mixtures in water also allow the taste to be recognized. This gives a rough idea of both the strength and the flavor. Recent experiments,[5] however, show that in tasting a large number of vanilla samples, the average ice cream manufacturer is unable to determine the difference between a true and an artificial extract. Furthermore, some tests show that it is not possible to tell whether a true or an artificial extract has been used in flavoring ice cream. The tests showed, however, that the true flavors tend to persist longer than the artificial. The type of extract the manufacturer should use seems to be an unsettled question. Some manufacturers claim that they do not use pure vanilla because it freezes out, or because its effect is nullified by freezing, and that artificial coumarin or vanillin is necessary to fortify vanilla and counteract this tendency. It seems logical, however, to suppose that over a period of time necessary for a true test the buying public will consume greater quantities daily when only the best natural flavors are used.

**Lead Acetate Test.**—Where normal acetate of lead solution is added to a suspected product, the absence of a precipitate is a conclusive evidence that the extract is artificial. A pure vanilla extract should yield, with lead acetate, a heavy precipitate, and should settle after a few minutes, leaving a clear, supernatant, partially decolorized liquid. Mere cloudiness may be due to caramel.

**Test for Coumarin.**—When potassium iodide is added in excess to an aqueous solution of coumarin, it forms a precipitate, "being at first brown and flocculent, afterwards, on shaking, clotting together to form a dark green, curdy mass, leaving the liquid perfectly clear."[6] The above are, of course, only simple qualitative tests.[7]

**Amount in Ice Cream.**—Vanilla extract is very volatile and should be added to the ice cream only in the freezer. The practice of adding it to the mix, either during preparation or while aging, is a wasteful one.

The amount of vanilla to use in ice cream is governed by so many different factors that no definite amount can be recommended. A strong-flavored ice cream may suit the public in one section of the country,

[5] Pierce, Combs, and Frost, Journal of Dairy Science, Vol. VII, No. 6, p. 585.

[6] Leach, A. E., Food Inspection and Analysis, p. 917. John Wiley & Sons, 1920.

[7] For quantitative tests, see Leach, Food Inspection and Analysis, 1920, pp. 919–927.

while the consumers in another section may prefer a light-flavored product. If the manufacturer is doubtful about the demand in his locality, let him make up a number of samples and get the opinions of a group of persons. This is a relatively inexpensive method of determining the public preference and has often proved effective.

Vanilla in small amounts brings out a flavor, just as salt does in cooking. A small amount, therefore, should be added to all flavors of ice cream. Usually half the amount used in vanilla ice cream is enough to augment the other flavor without giving a pronounced vanilla flavor.

**Oil of lemon** is made from the grated lemon rind "either by treatment with hot water, skimming off the oil which rises to the surface, or by pressure, or by distillation with water."[8] Great quantities of the oil are imported from Italy in copper flasks. It must be kept in a dark bottle and stored in a cool place between 30° and 40° F. because exposure to air and light in the presence of heat gives it the very undesirable flavor of terpenes.

**Oil of orange** is made from the rind of the orange in a manner similar to that described for lemon oil. Storage precautions mentioned for lemon oil apply in the same way to orange oil.

## CHOCOLATE AND COCOA

Chocolate is made from the cocoa bean, the seed of *Theobroma cacao*, a tree native to Central America and grown only in tropical regions. The tree is properly called the cacao, a term which is undoubtedly much like the name employed by the natives of Mexico, where the plant was first brought to the notice of Europeans. As a matter of fact, in the days of the Indian civilizations the cacao bean was used in Mexico for money. Chocolate was first introduced into Europe by Cortez. Since 1913 the world's production of cacao has nearly doubled, increasing from 253,144 metric tons to 499,723 tons, the latter being the figure for 1924. To-day the United States consumes one-third of the world's supply. Germany, The United Kingdom, France, and the Netherlands are the leading consumers in Europe.

In 1911 Ecuador was the greatest cacao-producing country, supplying 16 per cent of the world's production, but 1924 found her in third place with only a 10 per cent interest in the grand total. The African Gold Coast now produces 35 per cent of the world's cacao more easily and cheaply, and it is unlikely that Ecuador, with her labor shortage and haphazard methods, will ever regain her leadership. Nigeria, adjacent to the Gold Coast, now produces as much cacao as Ecuador. Brazil

[8] Leach, Food Inspection and Analysis, 1920, p. 938.

follows the Gold Coast with 14 per cent of the total; Ecuador, 10 per cent; Trinidad, 7; Dominican Republic, 6; Venezuela, 5; and all others, 23 per cent.

The name "cacao" is retained in most European languages, but in English, very curiously, it has been transformed into the word "cocoa," which belongs strictly to the cocoanut of the tropics.

The seeds are borne in a large pulpy fruit, about 10 inches long and 4 inches thick, containing 20 to 40 seeds. At the proper stage of maturity, the fruit is cut from the trees, split open, and its seeds (cocoa beans) removed. These are sometimes dried at once in the sun. For the production of a better-flavored product, however, they are allowed to undergo a fermentation process. When dried in the sun, the beans are roasted in revolving steel cylinders, after which the hulls are removed by machinery. The beans are then crushed and freed from the germs. The roasted and coarsely crushed product, freed from hulls and germs, is known as cocoa nibs. The nibs are thoroughly ground in stone mills, the material being reduced to a thin paste, which on cooling sets to a hard cake. This is known as unsweetened or plain chocolate and has approximately the following composition:

| | Per Cent |
|---|---|
| Water | 3 |
| Protein | 12 |
| Theobromine | 1 |
| Fat | 50 |
| Fiber | 3 |
| Carbohydrates (other than fiber) | 28 |
| Ash | 3 |

Cocoa is chocolate from which about one-half of the fat has been removed by pressing. The fat thus obtained is known as cocoa butter. Cocoa butter is often mixed with sweetened or milk chocolate to give it a glossy appearance for covering candies and Eskimo Pies.

**U. S. Standards.**—Chocolate is the solid or plastic mass obtained by grinding cocoa nibs without removing any constituent except the germ. It must not contain more than 3 per cent of ash insoluble in water, 3.5 per cent of crude fiber, and 9 per cent of starch, nor less than 45 per cent of cocoa fat.

Sweet chocolate is plain chocolate mixed with sugar (sucrose), with or without the addition of cocoa butter or flavoring material. It must not contain in the sugar-and-fat-free residue a higher percentage of ash, fiber, or starch than is found in the sugar-and-fat-free residue of plain chocolate.

Cocoa and powdered cocoa are the cocoa nibs, deprived of a portion of their fat and finely pulverized. They must contain percentages of

ash, crude fiber, and starch corresponding to those in chocolate, after correction for the fat removed.

Sweet or sweetened cocoa is cocoa mixed with sugar (sucrose) and containing not more than 60 per cent of sugar, and in the sugar and fat-free residue must not contain a higher percentage of ash, crude fiber, or starch than is found in the sugar and fat-free residue of chocolate.

The solubility of cocoa is a characteristic that is not correctly represented by that term, since only about 20–25 per cent of cocoa goes into solution. The processing of the seed causes such an alteration of texture, by the opening up or partial disintegration of the tissues, that the final product is rendered capable of suspension in such liquids as water or milk. The less the settling, the more desirable the product, other things being equal.

This characteristic is obtained during the manufacturing process by pulverizing, and, in some instances, by treatment with such alkalies as potassium or sodium carbonate, magnesium carbonate (Dutch process), solution of ammonia, or ammonium carbonate (German process).

The effect of the alkali is "to act upon a part of the fat, and produce a more perfect emulsion with less separation of oil particles."[9] Such treatment with alkali is regarded with disfavor, although it is not considered a form of adulteration. Cocoa thus treated is generally darker in color than the pure article. In most cases the use of alkali can be detected in the increased amount of mineral matters found in the ash, which in pure cocoa is about 4 per cent. Any appreciable amount above this may be attributed to admixture of mineral matters used in the preparation.

**Discoloration in Chocolate Ice Cream.**—A greenish-black discoloration in chocolate ice cream, according to Dahlberg,[10] is directly attributable to the tannins in cocoa. These spots develop in from one to ten days and are usually near a rust spot in the can, the iron reacting with the tannins in the cocoa to form ferric tannate. The flavor of these discolored sections is decidedly fishy. The ability of cocoa to produce this discoloration in chocolate ice cream may be determined by the addition of a few drops of 10 per cent solution of ferric chloride to 10 c.c. of a 5 per cent solution of cocoa. If tannin is present, an intense black results, indicating an alkaline solution. It is to be expected, then, that cocoas prepared with alkali, such as those made by the "Dutch process," will most frequently give positive results to this test. This discoloration can be prevented by testing cocoa, as already described, before using it to flavor ice cream, or by using well-tinned cans or paper liners, thus preventing contact with rust spots.

[9] Leach, Food Inspection and Analysis, 1920, p. 418.

[10] A. C. Dahlberg, Journal of Dairy Science, Vol. VI, No. 5, pp. 455–460.

**Adulteration.**—Common adulterants of chocolate and cocoa are sugar (when the product is not labeled "sweetened"), starches, cocoa shells, sand, wood fiber, and iron oxide—the last-named being used to give color. Starches, cocoa shells, sand, and wood fiber may be detected under the microscope. If cocoa is purchased from a reliable house, one need have little fear of adulteration.

Chocolate will keep for a long time without alteration when it is protected from the atmosphere. Chocolate articles should be kept in cool, dry storerooms. Heat causes volatilization of the aroma and facilitates the alteration by which cocoa butter becomes rancid; while dampness renders chocolate unsightly and promotes the growth of mold.

**Flavoring Ice Cream.**—One pound of cocoa or $1\frac{1}{2}$ lbs. of chocolate are required to flavor 10 gals. of ice cream. More chocolate is needed on account of its higher percentage of cocoa butter, which does not impart so much flavor as cocoa. It is the belief of some manufacturers that the cocoa butter in chocolate gives a more delicate flavor to the ice cream and that its use is worth while, notwithstanding the additional cost. The manufacturer, in using chocolate, should not deceive himself into believing that cocoa butter can be used to augment or supplement the butterfat in ice cream. The State and Federal Standards distinctly provide a minimum butterfat content.

Cocoa is more popular, however, and is usually added in the form of syrup. A simple formula for chocolate syrup is as follows: Ten pounds of cocoa and 15 lbs. of sugar are mixed dry and added to 3 gals. of boiling water. The mixture is stirred until dissolved and is then put into sterile cans and cooled. One gallon of this syrup should be used to flavor 10 gals. of ice cream.

It seems that certain of the chocolate flavors are volatile and are weakened by boiling. Some manufacturers stir the mixed sugar and chocolate, or mixed sugar and cocoa, into boiling water, cover, and cool immediately, keeping from the air until used. They believe that by so doing a better chocolate flavor is imparted to the ice cream. The syrup should be cooled before it is added to the ice cream. If this syrup is to be stored, it should be kept in a cold room to prevent fermentation.

Dahle[11] suggests that the best chocolate flavor for ice cream is made in the vacuum pan by the following method:

15 lbs. cocoa or 23 lbs. chocolate liquor
15 lbs. sugar
4 oz. gelatin
4 oz. salt
125 lbs. milk (skim or whole)

[11] Dahle, C. D., Ice Cream Review, January, 1926, p. 64.

The milk is dumped into the hotwell; the cocoa, sugar, salt, and gelatin are added; and the steam is turned on. Since the steam causes considerable agitation, little stirring is required to put the cocoa into its proper state. The batch is heated to 190–200° F. By this time the mass is usually homogeneous. All this is drawn into the pan and condensed to 10 gals., or a ratio of not quite 2 : 1. Three and one-half quarts of the mixture is sufficient to add to 5 gals. of mix.

A checking of the various formulæ for chocolate syrup at the California Agricultural Experiment Station showed that the formula and method as outlined above (with one exception: the salt was replaced by an equal quantity of cinnamon) gave a flavor rated above all others when submitted to competent judges.

**Chocolate-coated Bars.**—Chocolate-coated ice cream bars were introduced in 1921 as "Eskimo Pies." Vanilla ice cream, since it is the most popular, is nearly always used in these bars. The chocolate coating, especially prepared for this work, may be purchased from the chocolate companies. Ordinary candy coating or dipping chocolate gives too thick a coating. If used, it should be thinned with cocoa butter, care being taken not to increase the cocoa-butter content to such an extent that it predominates over the chocolate.

*Care of Dipping Chocolate.*—It is important to use the thermometer during the first melting and to avoid heating above 110° F. Although the warmer the chocolate, the thinner the coating on the bar, the ice cream must be very hard in order to take the higher temperature. The chocolate should be melted at a temperature of 110° F. and the dipping done at 90–95°. The chocolate should be stirred vigorously while melting, and often while in the dipping pan. When the pies come off the hooks and fall into the dipping pan, they should be removed at once. The chocolate is ruined for dipping if an appreciable amount of ice cream melts into it.

Arrangements should be made to use all the chocolate melted each day. If some is left in the melting kettle and some in the dipping pan, it is likely to gather moisture and become grainy.

The process of dipping is very simple. The ordinary brick of ice cream should be sliced horizontally into two pieces, each of which is then sliced into ten pieces. If the bricks are hard and a sharp knife is used, a smooth pie slice is obtained, which will not require as much chocolate as the pie slices that are rough and soft. To avoid trouble with softness, it is a good plan to have a quantity of pie slices in the hardening room some days before dipping.

Pieces of wire about 8 inches long are bent into S shapes. One end of the wire is then inserted into a slice of ice cream, which is dipped

into the chocolate and instantly removed, to be hung upon a rod over a drip pan. The chocolate hardens in a few seconds. The pie may then be removed from the hook and wrapped in foil or put in cartons and returned to the hardening room.

Other types of chocolate coatings, using a much greater quantity of dairy products, are also made and to some seem more desirable.

*Cocoa Coating.*—The following coating has been worked out by Iowa State College.[12] A powder is prepared by mixing together cocoa, dry skim milk, and powdered sugar in the ratio of 1 part of cocoa to 2 parts of dry skim milk and 3 parts of powdered sugar. It is very necessary that all three of these ingredients be as dry as possible and entirely free of lumps. The finer the mesh the more easily this is accomplished and the more uniform will be the finished coating. There is a tendency for the powdered sugar to lump if it contains too much moisture. Some powdered sugar contains considerable material that is undesirable for the preparation of this coating. If the powder is prepared in the proportions given above and thoroughly mixed, a very satisfactory, flexible coating will result. The second step in preparing this coating is to secure a good quality of unsalted, or at least very mildly salted, butter. Soften the butter by warming gently to the consistency to which butter is melted in preparing it for a moisture test. It should be thoroughly stirred while in this softened condition to distribute the moisture uniformly in the fat and to give it a uniform, creamy consistency. A small quantity of vanilla, usually $\frac{1}{2}$ oz. of pure vanilla extract, to each pound of butter used, will materially increase the palatability of the product. Butter with extremely high moisture will produce a very soft coating, while butter with very low moisture will produce a coating that is rather brittle and hard. The normal percentage of moisture in butter is most satisfactory.

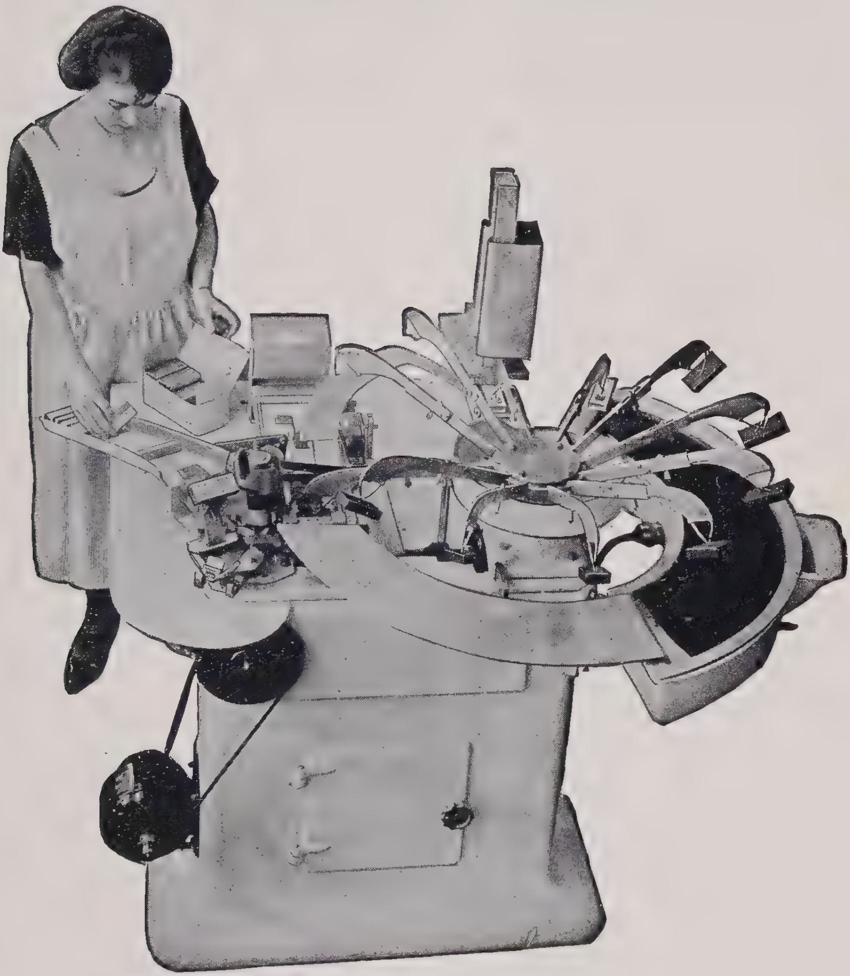
The softened butter, which has been prepared as indicated above, is mixed with the smooth powder which was previously prepared, in the ratio of $2\frac{1}{4}$ lbs. of butter to 2 lbs. of the powder. These are thoroughly mixed, and placed in a container, and heated with very little agitation to a temperature of 103–105° F. There is very little loss experienced by the use of this coating. It does not " go rough " like the ordinary chocolate coating, has about the same texture as the ice cream, is high in food value, and makes an excellent coating.

It is more desirable to make up the coating in the ice cream plant as needed rather than to make up a large supply and store it, as the butter becomes rancid unless stored at a very low temperature and the sugar crystals increase in size upon standing. It has been the experience of

[12] Iverson, C. A., Iowa State College, Ames, Iowa.

the authors that a given quantity of this coating will go considerably farther than the same quantity of ordinary chocolate coating as first described.

*Butterscotch Coating.*[13]—Butterscotch coating is made very similarly to the coating described above. The ingredients are put together in



*Courtesy Anderson Bros. Mfg. Co.*

FIG. 29.—Eskimo Pie Cutting and Wrapping Machine.

the same manner. For this coating, 1 part of dry skim milk and 2 parts of powdered sugar are thoroughly mixed together, making sure that they are perfectly smooth and free of lumps. Salted or unsalted butter may

[13] Iverson, C. A., Iowa State College, Ames, Iowa.

be used. The advantage of the unsalted is that there seems to be less tendency to foam or burn. The butter in this process may be heated rapidly at first with little danger, but care must be exercised after most of the water has boiled off and the temperature raises above 212° F. The curd has a tendency to settle to the bottom and therefore burns more readily. If this occurs, an undesirable flavor is produced. This condition is avoided by not heating too rapidly and by keeping the material agitated. The temperature should be raised to 280° F. At this temperature a slight burning of the butterfat results. The curd and salt may be removed at this point by straining through a cheese cloth. The clear, scotched butterfat is used for the coating. If a dull color appears on the finished ice cream bars, a little butter color may be added to the butterfat. This produces a brighter-colored coating and has a more attractive appearance.

Stir together this pure butterfat and the dry powdered mixture described above. Usually, equal amounts of each are used. If this ratio gives a coating that is too thick, it may be thinned by the addition or more butterfat; or, if the coating is too thin, it may be thickened by cutting down slightly on the butterfat. This coating contains no moisture and the ice cream should be dipped at 103–105° F. Care should be exercised to make sure that no water or melted ice cream gets into this coating or it will go rough and grainy, as happens under the same conditions with the chocolate coating.

Several machines have been devised for automatically cutting, dipping, and wrapping the bars. These materially reduce the labor cost, give a more uniform pie, and improve sanitary conditions of manufacture.

The special equipment necessary to make chocolate-coated bars in a large volume and the narrow margin of profit at the present popular price make this article occasionally unprofitable to the manufacturer.

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2. Zipper, The Manufacture of Chocolate and Other Cocoa Products. 2d Ed., Berlin, 1902.
3. Leach, A. E., Food Inspection and Analysis. New York, 1920.

## NUTS

Quite a wide variety of nuts may be used in the manufacture of special and nut ice cream. Among these are the almond, English walnut, pecan, filbert, black walnut, and peanut. The first two are by far the most extensively used. Nuts purchased in quantities large enough

to last over a period of time should be kept in dry cold storage at a temperature between 32° and 36° F.

**Almonds.**—Shelled almonds, commonly called meats, are the most economical form for the ice cream manufacturer to purchase.

Unshelled almonds keep better than the meats (unless they are in cold storage), since the latter easily become bruised and, once their skins are broken, rancidity seems to develop much more rapidly.

If the manufacturer has sufficient cold-storage space, there is no reason why he should not acquire his entire year's supply at one time. Almonds keep best in a cool dry place, preferably at a temperature of 32–36° F., or thereabouts. Nuts deteriorate when they are stored longer than a year, even under optimum conditions. When removed from cold storage, they are likely to become rancid very rapidly.

A study of the price fluctuations in almonds over a period of years shows no evidence of price cycles within a year, such as exist in the price of butterfat. One year the prices of almonds may be high and another year low; and, in any given year, prices may advance throughout the entire season. More often, the general price range will be about the same from beginning to end, the likelihood, of course, being that prices will advance as the season's supplies are sold out.

In the long run, the purchaser will do best to contract for a year's supply in August or September, which is the usual time for the bulk of the crop to be harvested.

The differences in the flavors of almond varieties are comparatively slight. A few varieties, notably the Texas, are slightly bitter. This flavor, however, is acceptable to many people. Others prefer an almond that is entirely sweet, such as the Drake. As a matter of fact, for ice cream purposes, the difference in flavor is so slight that price differential rather than a desire for a single variety, because of its superior flavor, should govern the buyer. In this connection, it should be stated that the most economical grade is the "sheller-run," a seedling almond, which emerges from the shelling machine without selection for size or quality of kernel. "Sheller-run," however, as put out by the California Almond Growers' Association, is guaranteed not to contain over 25 per cent almond pieces and to be entirely free from particles of shell or other foreign substance.

**Blanching.**—As the skin of the meat is somewhat bitter and tough, almonds that are to be used in ice cream should be blanched. Though machinery is available for doing this on a large scale, small quantities may be treated without it. The shelled nuts should be covered with boiling water, which should be poured off immediately. They are then plunged into cold water, which loosens the skins so that they are easily

removed. Three to 4 lbs. of almond meats is sufficient to flavor 10 gals. of ice cream.

If an oven is available, the almond meats may be browned and used in "toasted almond ice cream." Some manufacturers believe that such a name appeals to the appetite, thereby aiding in the sale of this special.

Should the manufacturer have a choice of varieties, the following table may be of value:

TABLE VI

COMMON ALMOND VARIETIES

| Variety | Number of Almonds per Pound | Percentage of Kernels to Whole Nuts |
|---|---|---|
| Nonpareil | 236 | 66.6 |
| I. X. L. | 152 | 52.28 |
| Ne Plus Ultra | 167 | 56.45 |
| Drake | 145.5 | 44.48 |

**English Walnuts** (*Juglans regia*).—It is probably more economical to purchase these nuts also in shelled form. The following table gives information on some of the common varieties, the figures being averages:

TABLE VII

COMMON WALNUT VARIETIES

| Variety | Weight of Nut in Grams | Number of Nuts per Pound | Per Cent of Meat | Specific Gravity |
|---|---|---|---|---|
| Placentia | 10.8 | 43 | 50 | 57 |
| Eureka | 14.5 | 32 | 47 | 66 |
| Chase | 12.0 | 38 | 47 | 63 |
| Concord | 11.0 | 42 | 52 | 63 |
| El Monte | 14.5 | 32 | 50 | 60 |
| Prolific | 12.0 | 38 | 50 | 60 |
| San José | 11.1 | 41 | 46 | 44.5 |

In the table above a very careful effort has been made to present average figures for the varieties given. The reader should know, however, that this is an extremely difficult thing to do, since some of the

varieties mentioned develop differently in various parts of the country, and furthermore, that nuts of the same variety vary widely on trees of different ages and under various conditions in the same locality. Again, especially in regard to weight and specific gravity, walnuts vary to a considerable extent from year to year. To obtain absolutely average statistics, it would be necessary to examine sample nuts from various parts of the country from trees of various ages, and on different types of soil, and from crops of several different seasons. It is impossible to obtain such samples at the present time in the case of practically all the varieties mentioned. The best that can be done is to present average figures for these varieties. An attempt has been made to bring out the comparative size and weight of the different varieties, and it is believed that the figures given are fair and representative in this respect.

**Percentage Meat.**—This figure represents the percentage of meat in the total weight of the nut. For instance, in the third variety given, Chase, there would be 47 lbs. of meat and 53 lbs. of shell in 100 lbs. of nuts. The percentage varies somewhat according to the degree of dryness of the nut. It is, therefore, impossible to give definite figures in this respect without some standard as to the dryness or moisture content.

In weighing the meat and shell, everything except the meat proper is included with the shell. The weight given for the shell, therefore, includes that of the septa or partitions between the divisions of the meat.

It will be noted that in all the good varieties the percentage of meat lies between 45 and 52. A variety that averages less than 45 per cent of meat in fairly dry nuts is not worthy of consideration, while one that runs over 50 per cent is exceptional. The comparative percentage of meat in the several varieties listed is influenced largely by the actual weight of the meat and shell. Some varieties have a good meat, but also a heavy shell, while others have no more meat to the nut, but a rather lighter shell, giving a higher percentage to a variety with less meat. Eureka walnuts, for instance, have 47 per cent meat as compared with 50 per cent or more in Placentia. The former variety, however, averages only 32 nuts to the pound. In other words, in one average Eureka nut, there are about 7 grams of meat, while in a Placentia nut there are only 5.4 grams, although the two nuts are of nearly equal size. Varieties like Eureka and El Monte have heavy shells, as well as heavy meats, as have also the Chase and the Prolific. This condition is indicated by the high specific gravity of these varieties.

**Specific Gravity.**—The specific gravity is obtained by dividing the weight in grams by the volume in cubic centimeters. This represents the comparative weight of nuts of the same volume or size in the different

varieties. For instance, with Chase and Placentia, which are practically of the same size, the weight of sacks of nuts of equal size would be as 63 to 57 in favor of Chase, while the number of nuts would be the same. Chase and Concord, having the same specific gravity, 63, would weigh alike in sacks of the same size, but more Concord than Chase nuts would be required to fill the sack, in the ratio of 19 : 17.5. Sacks of equal size, containing Eureka and San José would weigh 66 lbs. and 44.5 lbs., respectively, while at the same time the ratio would be 25 Eureka to 22 San José nuts. The most desirable qualities are high specific gravity, fairly large size, small number in a pound, and high percentage of meat.

## CHAPTER IV

# THE USE OF FRUITS IN ICE CREAM AND ICES

Although fruit ice creams and water ices are of great importance, fruits are not used as extensively, in these products, as conditions warrant. Generally, the proportion of fruit used is smaller than is required for the best quality of finished product, and too often the attempt is made to remedy the lack of fruit by the addition of artificial flavor and color.

The legal requirement of some states of a minimum of 3 per cent of fruit in fruit ice cream is altogether too low. In the case of many fruits, such an amount fails to impart to the ice cream or ice any detectable flavor or other quality of the fruit.

It is believed that the consumption of all ice cream and water ices, whether made with fruit or not, could be greatly increased if better fruit ice creams and fruit ices were made by the industry.

**Health Appeal.**—From the standpoint of healthfulness, fruit ice creams have a special appeal. In many ways, the constituents of fruits supplement those of the dairy products in the ice cream. The dairy products are rich in vitamins A and B, and for this reason stimulate growth and normal development; but they are, compared with many fruits, somewhat lacking in vitamin C, the anti-scorbutic vitamin. Children particularly require this vitamin in abundance, a fact that accounts for the widespread use of orange juice in children's dietaries.

Most fruits contain acids such as citric, malic, and tartaric, which are beneficial to health and, in addition, mineral salts that during metabolism give residues, basic in character, that tend to counteract the acid residues from a meat and cereal diet. These various beneficial properties of fruits have legitimate advertising value.

**Suitability of Various Fruits.**—At present, strawberries, raspberries, oranges, pineapples, maraschino cherries, peaches, bananas, and grapes are the most important of the fruits used in ice cream and water ices. These are all excellent, provided they are prepared properly and used in sufficient quantity.

Experiments made at the University of California,[1] however, have

[1] Turnbow, G. D., and Cruess, W. V., Bul. No. 434, University of California.

demonstrated that several other fruits are very desirable for use in the ice cream industry. Among these are prunes, which give a cream of rich flavor and attractive color, and, if sufficient fruit is used, a product with the well-known health value of prunes.

Figs are in a similar position, giving an ice cream of distinctive flavor, much appreciated by those who are familiar with this fruit.

Apricots, because of their deep, golden-yellow color, high acidity, and marked flavor, are excellent in ices, and also are very satisfactory in ice cream. The Royal and Blenheim varieties are rich in color and flavor and are recommended in preference to others. Canned pears give a cream of delicate but pleasing flavor and a very satisfactory ice. Recently, the avocado (alligator pear), a sub-tropical fruit of rich flavor and of buttery consistency, has been used in California in preparing an ice cream much in demand at exclusive hotels.

Persimmons, if soft-ripe, are excellent for use in ice cream. They give a golden-yellow color and a rich flavor.

Apple pulp and juice can be used in ice creams and water ices; but experiments indicate that these products would not meet with great popular favor because the consumer apparently prefers this fruit in its natural state, or, if associated with ice cream, as apple pie à la mode.

Raisins, particularly seeded Muscats, that have been canned to retain the original flavor, not only are very inexpensive but give an excellent cream.

In general, all fruits possessing sufficient flavor or color, or both, can be used successfully in ice cream and ices, provided enough of the fruit is added to impart to these products the unmistakable flavor of the fruit.

**The Importance of Variety.**—Not all varieties of a given fruit are equally desirable for use in the ice cream industry; those possessing the richest flavor and deepest color should be selected. Thus strawberries should be of varieties of deep color and firm flesh, and should be free of hollow centers. The Marshall is a good example of a satisfactory berry for ice cream use. The Banner, commonly grown in California, not only often lacks color but also has a large percentage of the berries hollow at the center.

Peaches for ice cream must be of marked flavor. The highly flavored table varieties, such as the Carmen, "strawberry," Elberta, and Lovell, are to be preferred to the canning varieties, such as the Phillips, Tuscan, and Muir.

The Royal Anne cherry is best for the maraschino process because of its light color and firm texture.

The eastern varieties of grapes, like the Concord and Pierce Isabella, are of more pronounced flavor and, therefore, are better for ices than are the European (Californian) varieties.

**Available Forms of Fruit.**—In most cases, the fresh fruit is to be preferred to all other forms, but in many localities it is too costly or is not available during the ice cream season.

The best substitute for the fresh fruit is that preserved in freezing storage and ordinarily known under the name of "cold-pack." Cold-pack strawberries and raspberries are very generally used in the trade. The ice cream manufacturer is in an excellent position to store fruit for his own needs in this manner.

Some fruits are canned in specially prepared forms for the ice cream trade, and although often excellent in quality are also often prohibitive in price if used in sufficient amount to give a real fruit product. In experiments at the University of California and in various ice cream factories, it has been found that the lowest grade of canned fruit, that is, solid-pack pie fruit, is eminently suitable for use in the ice cream industry and is of such low price that it can be used in generous proportions. Crushed pineapple, which was formerly in this class but which, on account of national advertising, has become somewhat higher in price than some of the pie-grade fruits, is nevertheless an excellent product for the purpose.

Fruit canners in California are equipped to pulp various fruits into the form of a puree for canning. Apricot pulp is obtainable in this form and is very satisfactory for use in the ice cream industry. All canning fruits lend themselves to this method of preparation.

Fruit preserves, particularly maraschino-style cherries, are used successfully in ice cream. Compared with the pie grade of canned fruit, the preserves are unduly costly. They also contain so much sugar that, if used in sufficient quantity to impart the flavor of the fruit, they reduce the freezing point and give too soft an ice cream.

Some fruits are available in crushed and sweetened form, preserved in glass with sodium benzoate. The frozen fruit is to be preferred as the benzoate injures the flavor.

A number of different dried fruits are satisfactory for use in ice cream. Of these, prunes, figs, raisins, and apricots are the best.

Fruits juices may be preserved in the frozen condition in the hardening room or may be obtained in bottled form, pasteurized. Of these, grape and loganberry are the best.

Recently an industry has been developed for the preservation of various juices by concentration. The products are known as concentrates; the orange, grape, and apple particularly are satisfactory for

use in the ice cream industry, although the fresh juices or those preserved by freezing are of better flavor than the concentrates.

Juices are also preserved successfully by the addition of sugars to give a heavy syrup; orange syrup thus prepared is one of the most satisfactory.

Experimentally at least, powdered fruit juices have been prepared in the same manner as milk powder and appear to have possibilities for use in the ice cream industry. Candied and glacé fruits are used to a limited extent in specialties but are rather too costly for general use.

Of the aforementioned products, it is practicable and usually profitable for the ice cream manufacturer to prepare or preserve for his own use the fresh fruits, cold-pack fruits, particularly berries, and maraschino cherries. He has facilities also for converting dried fruits and canned fruits into suitable condition for use in ice cream and ice. It is doubtful, however, whether it is advisable for him to can, dry, or preserve fruits, because of the expense and trouble involved. He will usually do better to buy such products.

**Characteristics of Fruit Flavors.**—Most fruit flavors are unstable and volatile. Severe temperatures or prolonged heating at moderate temperatures tend to drive off much of the flavor and to convert the characteristic and very desirable fresh flavor of the fruit into a "cooked flavor."

"Flavor" should not be confused with "taste." Sugar has a sweet "taste," fruit acid a sour "taste"; apricots and strawberries possess characteristic "flavors" and "aromas." Flavor is perceived in part by the palate and in part by the sense of smell, and is due largely to volatile compounds. "Taste" in its restricted sense refers to the non-volatile characteristics such as the "salty" taste of salt or the "sweet" taste of fruits or ice cream. "Aroma" is perceived by the sense of smell, and is very pronounced in some fruits. It is often more delicate than flavor and more readily injured by heat or other agencies.

Oxidation destroys flavor and aroma. Therefore, cold-stored fruits should be protected from contact with the air.

Volatile compounds are often lost when juices are concentrated by heat, or when fruits are converted into preserves by cooking.

Sugar tends to protect fruit flavors against loss by volatilization or change by oxidation or heat. Therefore, sweetened fruits retain their flavor better than the unsweetened.

Fruit flavors may be recovered from fruits by distillation, particularly *in vacuo* with alcohol, and some are available in concentrated form. So-called "true fruit" flavors usually consist in part of the real fruit

flavor thus concentrated; too often, however, these are "reinforced" artificially.

Natural fruit flavors are usually esters, i.e., naturally occurring compounds of a fruit acid and a fruit alcohol. Most of these are volatile and unstable. Some, such as methyl anthranilate of Concord grapes and ethyl butyrate of pineapple, have been identified and synthesized. F. B. Power, of the Bureau of Chemistry, United States Department of Agriculture, has conducted very elaborate studies of the flavoring compounds of various fruits, particularly grapes, apples, and peaches.

Artificial flavors are good in their place, but there is no excuse, except cheapness, for their use in fruit ice creams. One of the principal causes for the comparative lack of popularity of fruit ice cream is the use of artificial flavor. The addition of orange extract to orange ice or ice cream, and of artificial vanilla to vanilla cream, does not fall strictly within this category. The addition, however, of artificial strawberry or raspberry, pineapple, and banana flavors is inexcusable and reacts very unfavorably on the consuming public.

**When to Buy Fruits.**—For all varieties of fruit there is a seasonal peak when the particular fruit in question is most abundant and cheapest. If the ice cream maker will watch the daily market quotations during the fruit season and will occasionally visit the commission markets, particularly near week ends, he will be able to purchase job lots of fruit at low prices. These can be placed at once in the hardening room and worked up into final form for storage at leisure.

In some cases, those favorably located will find it feasible to deal directly with fruit growers or fruit growers' organizations and thus be assured of receiving fruit in the best condition at moderate cost.

**Use of Fresh Fruits in Season in Ice Cream.**—Usually the preparation of fresh fruits for use in ice cream is simple and requires only the equipment found in the average ice cream plant. The fruits may be considered conveniently by variety.

In all cases, without exception, the fruit must be thoroughly ripe; most fruits are best for ice cream when soft-ripe because they then possess their maximum flavor and may be thoroughly broken up and incorporated in the cream during freezing. If they are too firm, large pieces may be left in the cream and, because of low sugar content, may become "icy" in texture and thus injure the quality of the frozen product.

The ice cream mix referred to in the directions for use of fruit is found on page 136.

1. *Fresh Apricots.*—Use only soft-ripe, sound fruit, preferably of the Royal or Blenheim varieties. Wash to remove dust. Pit but do not

peel. Pass the halved fruit through a food grinder fitted with a medium-fine blade; the fruit should be quite finely ground. To each 4 lbs. of fruit, add 1 lb. of sugar. Boil for four or five minutes and allow to cool before use.

To 45 lbs. of ice cream mix, add about 9 lbs. of the pulp, about 17 per cent. To give 100 per cent overrun, approximately 12 gals. of frozen product should be obtained. The cream is really better if the vanilla flavor is omitted.

2. *Fresh Avocados (Alligator Pears).*—Use only soft-ripe but sound fruit. Peel and pit. Grind fine in a food chopper, and to each 4 lbs. add 1 lb. sugar. Mix well.

Add approximately 8 lbs. of the fruit, about 15 per cent, to 45 lbs. of mix.

This cream is much like pistachio ice cream in appearance and flavor.

3. *Fresh Bananas.*—Bananas are ripe when the skin has become yellow over the entire surface of the fruit and shows a few brown spots. For 5 gals. of mix, use 2 dozen large, or about $2\frac{1}{2}$–3 dozen medium-size or small bananas, or approximately 6 lbs. of the ground fruit to 45 lbs. of mix. Peel and grind medium-fine. No sugar or cooking is required.

4. *Fresh Blackberries.*—Prepared as described on page 72 for water ice. Blackberries can be used in ice cream in the proportion of about 7 lbs. to 45 lbs. of mix, but are more suitable for ice.

5. *Fresh Cherries.*—These are best if converted into maraschino cherries. See page 77.

6. *Fresh Figs.*—Where fresh figs are obtainable, as in California, Texas, Louisiana, and other Southern States, they may be used to excellent advantage in ice cream. Any variety, if soft-ripe, is satisfactory. Experimentally, the following procedure has given good results.

Cut off the stems. Grind the fruit medium-fine. There should be no large pieces. To 6 lbs. of figs, add $1\frac{1}{2}$ lbs. of sugar and boil for three or four minutes. Cool and use with 45 lbs. of mix. If white figs are used, a small amount of yellow color must be added.

7. *Fresh Lemons.*—Lemon ice is much more popular than lemon ice cream; nevertheless, the latter is occasionally in demand. The juice should be mixed with orange juice and sugar before addition to the mix, in order to avoid coagulation from excess acidity. To extract the juice, a small rapidly revolving porcelain or metal cone,[2] driven by a small motor, is best. Strain the juice to remove seeds. To 2 pts. of lemon juice, add 1 pt. of orange juice and 3 lbs. of sugar. This is enough for

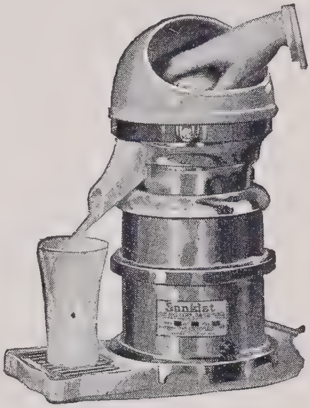
[2] These are used extensively at soda fountains and are obtainable from any fountain supply house or directly from the California Fruit Growers' Exchange, Los Angeles.

45 lbs. of mix. Add also a few drops of lemon oil or a small amount of lemon extract.

8. *Fresh Muskmelon: Cantaloupe.*—Peeled muskmelon or cantaloupe may be ground and put through a sieve to give a finely divided "puree." To 6 lbs. of the puree may be added 2 lbs. of sugar, with stirring, to dissolve. This is sufficient for 45 lbs. of mix.

9. *Fresh Orange.*—Oranges vary considerably in flavor and in acidity according to the variety and locality. Generally, the Valencia is superior to the Navel in flavoring power.

Extract the juice as directed for lemons, and strain to remove seeds and coarse pulp. To 2 qts. of orange juice, add $1\frac{1}{2}$ pts. of lemon juice and 3 lbs. of sugar. Add orange oil or extract to flavor, and orange color. This is sufficient for 45 lbs. of mix.



*Courtesy Calif. Fruit Growers Exch.*

FIG. 30.—Orange and Lemon Juice Extractor.

10. *Fresh Peaches.*—Only varieties of marked flavor should be used; most good table varieties will do. The skins of "slip skin" varieties may be removed easily by the following method: Dip in boiling water for one to two minutes and chill in cold water. Remove peels, cut in half, and pit. Grind to medium fineness. To 12 lbs. (or 6 qts.) of the pulp, add 3 lbs. of sugar. Boil three minutes and allow to cool. This amount is sufficient for 45 lbs. of mix. A little yellow or gold color may be required.

11. *Fresh Pears.*—Thoroughly ripe Bartletts are best, but any variety rich in flavor is satisfactory. Peel, core, and grind to medium fineness. Then proceed as directed for peach ice cream, using 10 lbs. of the pulp and $2\frac{1}{2}$ lbs. of sugar for 45 lbs. of mix. Yellow color is required.

12. *Prunes.*—See Dried Fruits.

13. *Fresh Raspberries.*—Proceed as with strawberries.

14. *Fresh Strawberries.*—As stated elsewhere, there is a great variation in the color, flavor, and texture of different varieties of strawberries, and for the ice cream makers' use those varieties that possess a deep, bright red color, solid flesh, and marked flavor are best. The Marshall, Ettersberg, and other good canning and preserving varieties are superior to the Banner, which is inclined to be light in color and often hollow and light-colored at the center of the berry.

Use at least 2 qts. (4 lbs.) of hulled and washed, thoroughly ripe berries. Crush or rub through a colander. This amount is enough for

45 lbs. of mix. Add one half the usual amount of vanilla flavor, and a small amount of red color if needed.

15. *Persimmons.*—This fruit, if completely ripened, that is, soft-ripe, is excellent for use in ice cream. It gives a product of golden-yellow color, smooth texture, and rich flavor. In experiments in the Dairy Industry Division of the University of California, the Hachya variety was used, but probably any good table variety, if thoroughly ripened, could be used.

Cut off the stem (and calyx) and separate the pulp from the peel. Grind fine or rub through a screen. To 8 lbs. of the pulp add 2 lbs. of sugar, and stir until dissolved. Add to 45 lbs. of basic ice cream and freeze in the usual manner.

**Fresh Fruit Ices.**—There is a very large potential field for fruit ices, undeveloped principally because in the past fruit ices have been poor keepers, often turning rough in texture or " bleeding " badly before they have been dispensed. The cost of the ingredients of fruit ices is low compared with those of ice cream. During the present " get thin at any cost " fad, there is a remarkable opportunity to expand the market for these refreshing and healthful products. The formula for a basic mix is given and fully discussed on page 23. In the directions that follow for the use of the various fruits, the quantities of fruits recommended are to be mixed with a sufficient quantity of the basic mix to give 5 gals. before freezing. The total acid of the mixture before freezing should be within the limits specified for water ices on page 24.

Fruit ices are usually frozen to yield not over 35 per cent overrun.

1. *Fresh Apricot Ice.*—Fresh apricots, prepared as described for ice cream, are suitable for apricot ice, but should be rubbed through a screen to remove pieces of skin and coarse fiber before being added to the basic water ice mix. Use approximately 12 lbs. or about 6 qts. of the apricot pulp and enough basic mix to give 5 gals., i.e., about 25 per cent by weight of fruit as calculated upon the total weight of fruit and mix.

2. *Fresh Blackberry Ice.*—Blackberries are better for use in water ice than in ice cream. To 12 lbs. of berries, add approximately 4 lbs. of sugar. Heat to boiling, stirring for about three minutes. Rub through a screen to remove most of the seeds. Add sufficient basic ice mix to give 5 gals.; i.e., use about 25–26 per cent of the prepared fruit, based on total weight of fruit and basic mix.

3. *Fresh Cranberry Ice.*—Cranberry ice is popular during the holiday season, either in brick form with vanilla ice cream and orange ice, or in bulk without admixture of other creams or ices. To 12 lbs. of the berries, add about $1\frac{1}{2}$ gals. of boiling water; allow to stand for two minutes, then

discard the water. This is to remove bitterness. Add another equal quantity of hot water and 3 lbs. of sugar, and boil until the berries are soft. Rub the berries through a colander or sieve. Add water ice basic mix to give 5 gals. this is equivalent to about 25 per cent of the prepared fruit in the final mixture.

4. *Currant Ice.*—Currants may be used as described for blackberries.

5. *Fresh Grape Ice.*—Eastern varieties, such as the Concord or Pierce Isabella, are best because of their pronounced flavor. A mixture of equal parts of Muscat, for flavor, and of red wine grapes, such as Alicante Bouschet or Zinfandel, may be used. Crush the grapes. Heat the mixture to 175° F. Strain at once through a sugar bag. Use 6 qts. of the juice with basic mix to give 5 gals., i.e., use about 25 per cent by weight. If the grapes are not thoroughly ripe, some sugar may be needed.

6. *Fresh Lemon Ice.*—Extract the juice as previously described for use in ice cream. To prepare 5 gals. of lemon-ice mix, take 3 pts. of lemon juice, add 3 lbs. of sugar and enough basic mix to give 5 gals.; i.e., about $7\frac{1}{2}$ per cent of lemon juice by weight. The proportion of lemon juice can be varied considerably. Add yellow color; if the flavor is too faint, add a very small amount of lemon extract or lemon oil.

7. *Fresh Loganberry Ice.*—Proceed as with blackberries or use 6 qts. of juice sweetened with 4 lbs. of sugar and added to sufficient basic mix to give 5 gals.; that is, use about 25 per cent of juice by weight.

8. *Fresh Orange Ice.*—To 6 qts. of orange juice extracted as directed for ice cream, add sufficient basic water-ice mix to make 5 gals.; i.e., use about 25 per cent of orange juice by weight.

9. *Fresh Peach Ice.*—Peel and pit as for ice cream. Use only highly flavored varieties. Then proceed as with apricot ice, adding color if needed.

10. *Pineapple Ice.*—Canned crushed pineapple is better than the fresh fruit. See page 18.

11. *Fresh Plum Ice.*—Damson, Satsuma, Grand Duke, Blue Diamond, and other varieties of deep-red or black color are very satisfactory in water ices.

Crush the plums. Add to 10 lbs. of plums about 1 gal. of water. Boil four to five minutes. Strain through a sugar bag. To each gallon of juice, add 3 lbs. of sugar. To 6 qts., add sufficient water ice mix to give 5 gals.; owing to the added sugar, this will be about 27–28 per cent of the sweetened juice by weight.

12. *Fresh Raspberry Ice.*—Proceed as with strawberries.

13. *Fresh Strawberry Ice.*—Crush 10 lbs. of ripe berries of deep-red color. Add 3 lbs. of sugar and stir until dissolved. If not very finely

ground, rub through a sieve or colander. Add basic ice mix to give 5 gals.

14. *Fresh Cherry Ice.*—Use soft-ripe, sour, red or black cherries. Crush thoroughly the flesh and a few of the pits. To 10 lbs. of the cherries, add 3 lbs. of sugar. Heat to boiling for three to four minutes. Strain through cheese cloth or sugar bag and press out all juice possible. Add basic ice mix to give 5 gals.

**Preservation of Fruits by the Cold-pack Method.**—Most fruits can be preserved with practically all of their fresh color and flavor if they are stored in sealed containers at a freezing temperature. In commercial practice, barrels have been the principal containers for frozen fruits. From the standpoint of economy, they are superior to other vessels; but from the standpoint of quality of product and convenience to the ice cream maker, they are inferior to enameled cans of gallon or No. 10 size.

The barreling of berries, particularly strawberries, has become a very important industry and one of the chief sources of supply for the ice cream industry. The Pacific Northwest and the Watsonville district in California are important centers where this practice is followed. The cold-packing of strawberries will serve to illustrate the usual commercial process, which can be readily applied in the ice cream factory.

1. *Cold-packing of Strawberries.*—Strawberries are grown principally for the fresh market and for the preserve industry. For this reason, it is only during the peak of the season (in California there are two seasonal peaks) that berries are sufficiently abundant and cheap for cold-packing.

Strawberries for cold-packing for the ice cream trade should be of deep color and good flavor and, if possible, relatively free from hollow centers. The Marshall is typical of the most desirable varieties.

Industrially, cold-packing is conducted in or adjacent to commercial refrigerator warehouses, although it is often a separate enterprise. Several fruit-canning and preserving plants in the Pacific Northwest also prepare and distribute large quantities of cold-pack berries. Therefore, the ice cream trade has available a large supply of barreled berries and need not engage in the business of cold-packing to obtain the fruit needed. However, many ice cream factories are located in berry districts and can often buy fruit to advantage during the season and store it until needed. In addition to a saving in cost, there will be, if the storage is properly maintained, an improvement in quality, as long shipment and prolonged storage sometimes cause loss of color and flavor in the commercial pack. Frequently the commercial or " jumbo " pack is of poor quality, made up largely of injured and surplus berries from the fresh market.

For those ice cream makers who may wish to cold-pack berries for their own use, the following procedure may be recommended.

Use only fresh and sound berries free from visible injury or decay. Remove stems. Rinse berries in cold water and drain. Pre-chill berries in storage room before packing. Remove one head from a paraffined barrel or keg by loosening the hoops. For the average factory, 10-gal. kegs or 25-gal. barrels are often more convenient than 50-gal. barrels; the berries in the latter may darken or spoil after the barrel is opened if all the fruit cannot be utilized promptly.

Weigh enough berries to fill the barrel or keg, and one-half as much sugar as of berries. Place a shallow layer of sugar in the bottom of the

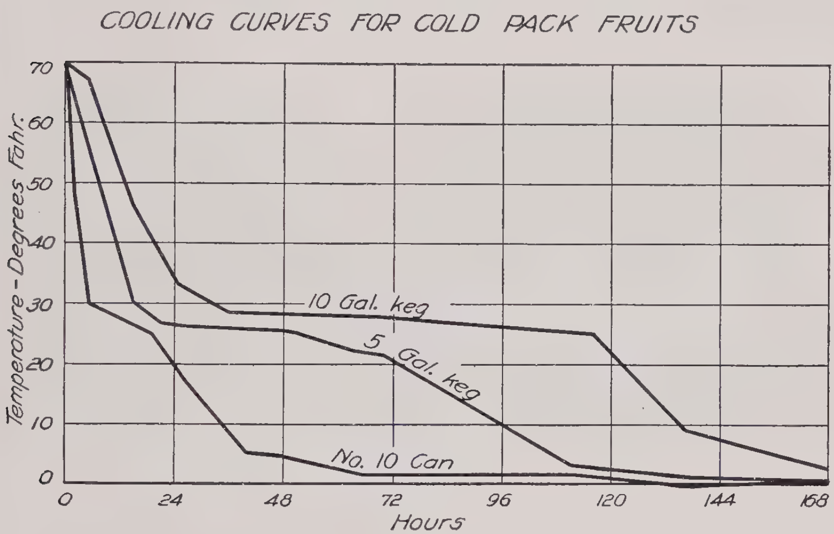



FIG. 31.—The Curves Picture the Necessity of Precooling Fruits for Cold Packing.

barrel and add about twice its weight of berries; then alternate layers of berries and sugar. In this manner, fill the barrel to within about 1 inch of the chime with berries and sugar, finishing with a layer of sugar. Rock the barrel back and forth vigorously while filling, to compact the fruit and sugar and thus exclude air as far as possible. Insert the head and drive the hoop into place. Roll the barrel at once into the hardening room at not above 15° F., preferably at a temperature of 10° F. or less. As a safety precaution, it is advisable to bore a $\frac{1}{4}$-inch hole in the head to serve as a vent should the fruit ferment before it cools to the cold-room temperature.

Small kegs will cool quickly without danger of spoiling, but in 50-gal. barrels the center of the mass cools very slowly, and if the fruit, sugar,

and barrel are warm, fermentation may occur before a preserving temperature is reached. It is advisable, therefore, to chill the stemmed, washed fruit and the sugar at 32° F., in dishpans or in ice cream brick pans for several hours before packing, if all danger of fermentation is to be avoided.

A very satisfactory container is the No. 10 fruit can, as it cools quickly in cold storage and is easily handled. For berries, cans that are enameled inside, i.e., coated with a special lacquer, should be used. The enamel prevents contact of the berries with the tin. Satisfactory hand-power sealers are obtainable for about $20 each. A convenient method of packing the fruit into the cans consists of first mixing two parts of fruit, by weight, with one of sugar, in a large container such as a copper kettle or large dishpan, and packing the mixed berries and sugar

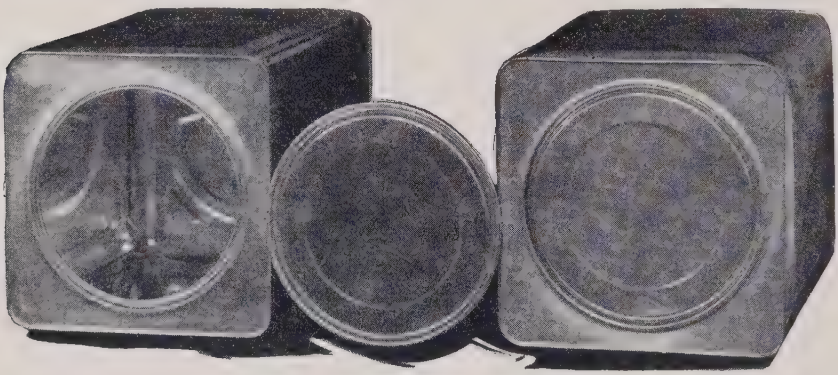


Fig. 32.—Desirable Type of Double Friction Seal Five-gallon Can; Lacquered Inside and Out, for Storage of Cold Pack Fruits and Berries.

into the cans and sealing tightly. Friction-top cans that require no special sealing device, such as are commonly used for corn syrup, can also be obtained.

A convenient container is an ordinary 5 or 10-gal. ice cream can. It should first be coated on the inside with melted paraffin. The berries and sugar in a 2 : 1 ratio should be mixed as they are packed tightly into the can, to within about 2 inches of the top. The can should be placed at once in the hardening room and, when the fruit has hardened, a layer of water poured on the surface to form an air-tight seal of ice which protects the berries against browning by the air. Milk cans may be used similarly.

Berries for the preserving trade are often packed with an equal weight of sugar; these are rather too sweet for use in ice cream. If

packed with less than 1 part of sugar to 2 of berries, there is some danger of spoiling.

The temperature of the cold room must be maintained at a low point, preferably below 15° F. Any temperature below this, even below 0° F., is satisfactory.

Prompt cooling after packing is vitally important; slow cooling permits fermentation and may result in complete loss of the fruit. For this reason, paraffin-lined cans or other small containers are to be preferred to 50-gal. barrels for storage of frozen berries packed at the ice cream plant.

2. *Cold-packing of Other Berries.*—Loganberries, blackberries, raspberries, cranberries, etc., may be packed and preserved in freezing storage as previously described for strawberries. Small containers of 1–10 gals. capacity, rather than 50-gal. barrels, should be used, in order to promote rapid cooling and thus prevent loss by fermentation or molding. As with strawberries, prompt cooling and as complete exclusion of air as is possible are necessary.

3. *Cold-packing of Other Fruits.*—Thoroughly ripe apricots should be pitted and washed and mixed with 1 part of sugar to 2 of fruit. The mixture should then be crushed in some convenient manner, thoroughly mixed and packed and stored as described for berries.

Peaches may be peeled as directed on page 71, ground, mixed with sugar, and packed in the same manner as strawberries.

**Using Cold-pack Fruits.**—The cold-pack fruits should be allowed to thaw before use; this can be done conveniently by removing from the storage container the amount required for the day's run and quickly melting it in a steam-jacketed kettle. If added in the frozen state to the mix, they would remain rough and fill the finished product with ice crystals.

Use the same quantities, by weight, of the cold-pack fruits in ice cream and water ices as directed for the fresh fruits. These quantities will in most cases represent slightly less original fruit, but, owing to the fact that the cold-pack fruits contain considerably more sugar than the prepared fresh fruits, the addition of too large a proportion of the cold-pack fruit is apt to cause too great a lowering of the freezing point and give too soft a frozen product at the usual holding temperature.

**Preparation of Maraschino Cherries.**—The industry uses a large quantity of prepared cherries in ice cream. Practically all of these are artificially colored and flavored according to the maraschino process. Frequently, the ice cream manufacturer can purchase the broken maraschino cherries at such a low cost that, if time and materials are considered, it would not be profitable for him to prepare cherries from the

fresh fruit for his own use. The process is, however, not difficult, and to those who wish to prepare their own cherries the following method can be recommended:

1. *Choice of Fruit for Maraschino Process.*—Use only white or light-pink varieties, such as the Royal Anne or White Republican, etc. Choose firm-ripe, not soft-ripe fruit.

2. *Treatment in Sulphurous Acid Brine.*—To prepare a satisfactory product, the cherries must be stored in sulphurous acid solution for at least one month in order to harden the tissues and to bleach the color.

Remove one head from a clean paraffin-lined barrel, by loosening the hoops. Pack the cherries, unstemmed, into the barrel. Put the head in place and drive the hoops tightly to make the barrel water-tight.

Prepare, for a 50-gal. barrel, about 25 gals. of sulphurous acid solution, as follows:

| | |
|---|---|
| Water | 23 gals. |
| Six per cent sulphurous acid solution | 2 gals. |
| Salt | 10 lbs. |

Fill the barrel completely with this solution, and drive the bung in place. Store in a cool room *but not in cold storage*—in the cold room the fruit will freeze and become soft.

Instead of the above solution, the following may be used:

| | |
|---|---|
| Water | 25 gals. |
| Bisulphite of soda | 3 lbs. |
| Salt | 7 lbs. |
| Citric acid crystals | 1 lb. |

Dissolve all ingredients well; the solution should always be made up in a *wooden container*, never in metal, as it is very corrosive.

The bisulphite or 6 per cent sulphurous acid solution can be had from any chemical supply house or from most ice cream supply houses.

Store for four weeks or longer before proceeding with the remainder of the process.

3. *Purchase of Cherries in Sulphurous Acid Brine.*—Both imported and domestic cherries preserved in 50-gal. barrels in the sulphurous acid solution, can be purchased, often at lower cost than the fresh fruit. These cherries are generally satisfactory.

4. *Preparing for the Syrup Treatment.*—Drain off and discard the storage liquid. Remove one head of the barrel. Stem the cherries and pit them. Inexpensive but efficient hand pitters are obtainable at any hardware stores.

Next follows boiling to remove all taste of the sulphurous acid and salt. Place the pitted cherries in a copper, aluminium, or glass-lined kettle and add water to cover generously. Boil vigorously for five minutes. Drain off and discard this water. Cover again with fresh water. Boil five minutes and discard the water. Repeat at least once again, preferably twice, that is, until the cherries are tender and the fruit is practically free of "sulphur" and salt taste. Usually, at least twenty minutes' total boiling is required.

5. *Syrup Treatment.*—Prepare sufficient syrup of the following composition to cover:

| | |
|---|---|
| Water | 5 gals. |
| Sugar | 15 lbs. |
| Citric acid crystals | 5 oz. |

Color red to the tint desired. The best color is a mixture of equal parts Amaranth and Ponceau-3-R. For this mixture, about 0.1 of 1 per cent of the dry colors is needed, that is, for the above amount of syrup, about $\frac{3}{4}$ oz. of the mixed dry colors. For practical purposes, however, merely add what appears to be enough of the red color solution used for strawberry ice cream.

Place the cherries from Step 5 in a kettle. Cover generously with the syrup. Boil three to four minutes and then set aside in agate-ware or aluminum pans for twenty-four hours.

The next day, drain off the syrup and measure it. Test it with a Balling sugar hydrometer or a Baumé hydrometer, and add and dissolve sugar to bring it to 35° Balling or to 18° Baumé. If a hydrometer is not at hand, merely add to each 5 gals. of syrup about 6 lbs. of sugar. If more color is required, add it at this time.

Boil the fruit and syrup together for three to four minutes and again set aside for twenty-four hours.

Then drain off the syrup and add sugar to bring to 40° Balling or to 21° Baumé, or merely add to each 5 gals. of syrup about 6 lbs. of sugar. Boil as before for three to four minutes.

Set aside for twenty-four hours. Drain off the syrup and add sugar to bring to 40° Balling or 21° Baumé (there will have been a decrease during the twenty-four hours); or add about 2 lbs. of sugar to each 5 gals. or syrup. Also add cherry flavor (or a few drops of bitter almond oil) to give the flavor desired. Then proceed with Step 6.

6. *Preserving the Maraschino Cherries.*—Again heat the fruit and syrup to boiling for one minute and pack, scalding hot, in jars. Place the rubbers on the jars and attach the caps loosely to permit escape of steam during sterilizing.

Place the jars at once in a steam box, such as is sometimes used for sterilizing milk cans. Turn on the steam gradually and leave for twenty minutes. Remove the jars and screw or clamp the lids on tightly.

Another and simpler method is to allow the fruit and syrup to cool overnight and then pack it into kegs or jars and store in the cold room at 15° F., or less. Tin ice cream cans, *if heavily and completely lined with paraffin,* can also be used. In this case, after freezing, seal with a layer of water over the cherries. If the tin is not well coated with paraffin, the cherries may react on the metal with disastrous results. For this reason it is not safe to use ordinary tin fruit cans.

The syrup from the cherries can be used to advantage for flavoring and coloring cream and need not be wasted.

7. *Maraschino Cherry Ice Cream Formula.*—Every experienced ice cream manufacturer has his favorite formula. The following one has been used quite successfully: To 45 lbs. basic mix, add $2\frac{3}{4}$ lbs. of ground cherries; color and flavor to suit.

**Strawberry and Other Fruit Preserves.**[3]—Fruit preserves for the ice cream maker need not be whole; that is, broken or crushed fruit is just as satisfactory; therefore, less care and skill are required than for preparing preserves for table use. While maraschino cherries are the most important of the fruit preserves for the ice cream trade, a considerable quantity of strawberry and other fruit preserves are used. In general, the fresh or the cold-pack fruits are to be preferred to the preserves because of their better color and flavor and much lower sugar content.

The general procedure for preparing fruit preserves is as follows:

Berries are stemmed and washed; other fruits, except apricots, are peeled (pitted, if necessary) and coarsely ground. To each pound of the prepared and crushed fresh fruit, add 1 lb. of sugar.

To strawberries and raspberries, add artificial color, preferably a small amount of Ponceau and Amaranth.

Boil the fruit and sugar to a boiling point of about 218–219° F., or, if a suitable thermometer is not available, boil about five minutes. Pack and seal, scalding hot, in glass-top fruit jars. Invert to cool, or cool and store as cold-pack fruits at 15° F. or lower, as previously described for maraschino cherries.

All berries, canned crushed pineapple, apricots, and highly flavored peaches may be made into preserves in this manner.

[3]A full description of the preparation of fruit preserves will be found in Cruess, W. V., Commercial Fruit and Vegetable Products. McGraw-Hill Book Company, New York.

**Crushed Fruits.**—Any soft fruits, such as berries, apricots, pears, and peaches, may be crushed, mixed with 1 part of sugar to 3 of fruit, by weight, and the mixture boiled three to five minutes and sealed, scalding hot—in jars or cooled and stored in suitable containers, as described for cold-pack fruits, at 15° F. or lower. These are used in the same manner as cold-pack fruits.

**Preparation and Use of Candied Fruits.**[4]—Broken pieces of candied fruit are packed for the ice cream trade by all commercial candied fruit factories, and, being a by-product, are obtainable at moderate cost.

The process of making candied fruit is long-drawn-out, requiring considerable skill, but is fully discussed in the textbook listed in the footnote.

Candied fruits are used in such specialties as tutti frutti, parfaits, puddings, etc., being chopped in small pieces before addition to the cream. They are also suitable for use in aufait creams. See page 21 for description of these specialties.

**Preparation and Preservation of Fruit Juices.**[5]—Fruit juices for use in ice cream and water ices are best when freshly expressed, but unfortunately the fruit season is short and it becomes necessary to preserve the juice. Three practicable methods are available: (1) by cold storage; (2) by pasteurization; and (3) by preservatives. Of these, cold storage is the least injurious to the fruit flavor and is also the simplest and least expensive from the ice cream maker's standpoint.

1. *Preservation of Fruit Juices by Cold Storage.*—The various berry juices may be expressed as directed on pages 72–73, for use, fresh, in ices. This process consists essentially in heating the crushed berries to the simmering point, 175–180° F., and draining through a sugar bag. To the juice should be added 1 lb. of sugar to each 2 pts. or 2 lbs. of juice, and the juice should be stored at 15° F., or below, in large demijohns filled only two-thirds to three-quarters full, or in paraffin-lined cans or kegs.

Red grape juice can be prepared in a similar manner. Use Concord, Pierce Isabella, or a mixture of equal parts Muscat grapes and a red wine variety such as Alicante Bouschet.

The containers should be sealed or tightly covered to exclude "cold-storage" odors and flavors.

Usually, cull citrus fruits may be had at low prices in California

[4] For discussion and description of this process see Cruess, W. V., Commercial Fruit and Vegetable Products. McGraw-Hill Book Co., New York.

[5] A complete discussion of this subject is not feasible in this text; for a more complete description of methods, see Cruess, W. V., Commercial Fruit and Vegetable Products.

during the winter months, and, for those favorably situated, it may be profitable to prepare the juice from such fruit and preserve it by cold storage for early summer use.

The juice may be extracted from the halved fruit by means of the small, mechanically operated juice extractors described earlier in this chapter. It should be strained to remove coarse particles. Add sugar, 1 part by weight to 2 parts juice. This is about $4\frac{1}{2}$ lbs. sugar to each gallon of juice: Dissolve the sugar. Place at once in well-paraffined milk cans and store at 15° F. or less. When it is well chilled, place a layer of water, about 1 inch deep, on the surface, to exclude air.

Other fresh juices may be preserved as described above.

2. *Preservation of Fruit Juices by Pasteurization.*—Berry and grape juices are easily preserved by heat (pasteurization) in sealed bottles. Cirtus juices lose their flavor by such treatment, and should be preserved by cold storage rather than by pasteurization.

To use this method, pour the juices, mixed with sugar, 1 part to 2 of juice, into crown-finish bottles, to within about $1\frac{1}{2}$ inches of the top. Seal the bottles with an ordinary home-size "beer-bottle capper" and "beer-bottle caps." Place the bottles in a kettle; cover completely with water and heat to 180° F. for thirty minutes. Pour off the water. Allow bottles to cool. Store away from the light.

Bottled juices are on the market at moderate prices, and most ice cream manufacturers use these in preference to pasteurizing juices for their own use.

3. *Preserving Juices by Benzoate.*—Any juice may be easily preserved by adding .2 of 1 per cent of sodium benzoate; this is approximately 12 oz. to 50 gals. of juice. It injures the flavor, and its use in a product for ice cream making is not recommended. Its presence must be declared on the label of products offered for sale.

4. *Use of Fruit Juices in Ice Cream and Ice.*—Juices preserved in any of the aforementioned ways are used in the manner described on pages 69–72, for the fresh juices. In most cases, about $1\frac{1}{2}$ gals. of the juice is mixed with basic water ice mix (see page 23 for formula) to give a total of 5 gals. On freezing, an overrun of about 35 per cent should be obtained. If the juice has been heavily sweetened, use less than directed above or use less sugar in the basic mix.

**Fruit Syrups.**—Fruit syrups are fruit juices sweetened to the consistency of a syrup by the addition of cane sugar. To the fresh juice is added approximately 8 lbs. of sugar to the gallon. The syrups are preserved as described for fruit juices. The best method is by storing in the hardening room or other freezing storage at 15° F. or lower. In general, the juices, to which less sugar has been added, are

preferable to the syrups; and the preparation of syrups, other than those of citrus fruits, is not strongly recommended.

**Fruit Concentrates.**—These represent the natural juices, concentrated, *in vacuo* or otherwise, to a heavy syrupy consistency. Special and costly equipment is required, and their preparation in the ice cream plant is impracticable unless the plant possesses a vacuum pan.

They are, however, a convenient form in which to purchase and use fruit juices. By diluting most concentrates with about 5 parts of water, the composition of the fresh juice is approximated. Orange concentrate is, when fresh, excellent for use in ice cream and ices.

1. *Orange Ice with Concentrate.*—The Dairy Industry Division of the University of California has found the following formula satisfactory:

| | |
|---|---|
| Orange concentrate | 15 oz. |
| Fresh orange juice | 15 oz. |
| Orange oil | 10 drops |

Add basic water ice mix to give 5 gals. and color to give desired tint.

2. *Ice Cream with Orange Concentrate.*

| | |
|---|---|
| Orange concentrate | 15 oz. |
| Fresh orange juice | 15 oz. |
| Orange oil to flavor | 6 to 10 drops |

Add 45 lbs. of standard mix and color as desired.

**Use of Canned Fruits.**—Some varieties and grades of canned fruits are excellent for use in ice cream or ices. These may be purchased for less than it would cost the ice cream manufacturer to buy and can the fruit. It is, therefore, not recommended that he conduct this operation himself.

1. *Suitability of Various Grades of Canned Fruits.*—The grade of canned fruit best suited for use in ice cream is the solid-pack pie grade. This can be purchased by the case directly from canners or canned-food dealers. This grade contains no added sugar or syrup and contains a maximum of fruit. It is not only the best grade for ice cream use but is the lowest in price.

2. *Ice Cream with Canned Apricots.*—Grind the fruit from one No. 10 can of solid-pack pie-grade apricots to a fine consistency. Add during freezing to 45 lbs. of basic ice cream mix. This corresponds to approximately 13 per cent of fruit.

3. *Water Ice with Canned Apricots.*—Prepare one No. 10 can of the apricots as for use in ice cream, and add sufficient basic water ice mix to give a volume of 5 gals.

4. *Ice Cream with Canned Figs.*—Using the solid-pack white figs, preferably of Calimyrna variety, grind the contents of one No. 10 can to medium fineness and use as described for apricot ice cream. This is an excellent cream in every respect and has proved popular wherever introduced.

5. *Crushed Pineapple.*—See p. 18.

6. *Use of Other Canned Fruits.*—Peaches usually lack flavor, and on this account 20 per cent by weight is required; that is, about $1\frac{1}{2}$ No. 10 cans (about 9 lbs.) of the ground peaches is added to 45 lbs. of basic mix. The flavor and texture are improved if the ground fruit is first cooked for five minutes with 1 part of sugar to 3 parts of fruit.

The same considerations apply to solid-pack pie pears. Pear ice cream possesses a delicate but very pleasing flavor and should prove popular. However, not less than $1\frac{1}{2}$ No. 10 cans to 45 lbs. of mix should be used.

**The Use of Dried Fruits in Ice Cream.**—Some varieties of dried fruits are well adapted to use in ice cream. Of these, prunes, figs, raisins, and apricots are most suitable for the purpose. Dried fruits are not expensive and add very little to the cost of the finished product.

For example, for prune ice cream, containing 20 per cent by weight of prune pulp, the cost of the fruit for 45 lbs. of mix is at present (1927) about 40 cents. The 45 lbs. of mix plus the fruit will naturally yield a larger volume of cream at 100 per cent yield than will the 45 lbs. of mix without added fruit. On this basis of calculation, it is seen that the cost of the fruit adds little, if anything, to the cost of the ice cream. Less amounts of figs, raisins, or apricots are required than of prunes.

The fruits will be considered in the order of their importance for use in ice cream.

1. *Prune Ice Cream.*—Prune ice cream containing about 20 per cent of the prepared fruit may be considered a " health product " as well as a specialty for dessert purposes. Some manufacturers find a good demand for prune ice cream for convalescents in hospitals. Retail dealers could easily develop a demand for such a cream for serving in the home to children and in the sick room, because of the well-known health value of this fruit.

It is hoped that canners will soon place on the market canned prune pulp containing about 40 per cent total solids, for ice cream use, as this product, prepared experimentally at the University of California, has proved convenient and very satisfactory for use in ice cream.* It is not yet available, however, and the ice cream maker must, therefore, prepare his fruit in the following manner. To about 7 lbs. of prunes, add approximately 4 qts. of water. Bring to a boil and set aside overnight.

Author's Note to Second Edition.—Canned prune pulp is now available to the trade and has been found to be very desirable for use in ice cream.

Boil gently for a few minutes until soft. Put fruit through a colander or coarse screen and mix with the water in which it was cooked, or if desired, pit the prunes and then grind the pitted fruit. Add 12 lbs. of this pulp to 45 lbs. of basic ice cream mix. This gives a cream rich in prune flavor and possessing the health value of the fruit. For a cream of milder flavor, use 7 lbs. of the pulp to 45 lbs. of basic ice cream mix.

2. *Raisin Ice Cream.*—Unfortunately, commercial ice cream makers have generally made the mistake of using the Thompson Seedless raisin instead of the seeded Muscat. The latter possesses a rich flavor that carries well in the frozen product, whereas the Thompson is practically devoid of flavor, its principal virtue being its convenience.

One cannery[6] in California prepares canned Muscat raisins that are ideal for use in ice cream. If these are obtainable, grind 4 lbs. of the raisins coarsely and mix with 3 lbs. of the whole canned raisins. To the mixture add 45 lbs. of basic mix. If the bulk raisins are used, add to 5 lbs. of seeded Muscats (packed *without oil coating*) 3 pts. of water. Mix well. Heat to the simmering point (above 160–170° F.) in a kettle and set aside for about one hour to permit absorption of water. Grind one-half of the raisins and leave the remainder untreated. Use about 7 lbs. of this mixture with 45 lbs. of basic mix.

3. *Dried Figs in Ice Cream.*—Dried figs, preferably Calimyrna, require the addition of sugar and considerable cooking. While any one of several satisfactory methods can be used, the following has been found the best of those tested by the University of California:

| | |
|---|---|
| Dried figs | 2 lbs. |
| Sugar | $1\frac{1}{2}$ lbs. |
| Water | about 3 qts. |

Soak fruit in water overnight. Then add sugar. Cook gently until tender—one hour or longer. The finished weight should be about 6 lbs.; if less, add water; if more, boil off excess water. Grind to medium fineness. Add to 45 lbs. of basic mix.

The cooked whole figs, if desired, may be cut in half and used in the preparation of an aufait.

4. *Dried Apricots in Ice Cream.*—If canned solid-pack pie-grade apricots are not available, the dried fruit may be used.

| | |
|---|---|
| Dried apricots | $1\frac{1}{2}$ lbs. |
| Sugar | 1 lb. |
| Water | About 3 qts. |

[6] The Kings County Packing Co., Armona, California.

Soak fruit in water overnight. Add sugar. Cook slowly until soft, adding more water during cooking if needed. Bring total weight to about 6 lbs. by boiling off surplus water or by adding water, as the case requires. Grind and add to 45 lbs. of basic mix.

**Other Frozen Desserts with Fruit.**

1. *Nuts in Ice Cream.*—The choice, preparation, and use of nuts in various types of ice cream is fully discussed on pages 60–64.

2. *Aufait.*—See pages 16, 21 for definition and formula; this is an excellent medium for larger pieces of candied fruit and firm fruit preserves.

3. *Puddings.*—Nesselrode, Plum, Manhattan, and Oriental puddings are fully described on page 20. Candied, dried, and preserved fruits and nuts are suitable for use in these specialties.

4. *Lacto with Fruits.*—For description and formula, see page 21. Some fruits, particularly the fresh, may be used in lacto.

5. *Frappé with Fruit.*—This is only partially frozen, and for this reason fruit pulps and some fruit juices may be added to advantage. Banana, pineapple, strawberry, apricot, and finely sieved prune pulp are suggested.

6. *Punch.*—Punch is an excellent outlet for highly flavored fruit juices such as loganberry, orange, and grape. Other liquids permitted under the Volstead Act may be added to suit the case.

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# CHAPTER V

## INGREDIENTS OF THE MIX

THE material in this chapter is treated from two different angles. In the first part the multiplicity of the sources of the ingredients is discussed, while in the second, the structural and chemical nature of the products is considered.

### BUTTERFAT

Milk.—The primary source of fat in ice cream is milk, for which no substitution should ever be allowed. Milk is concentrated in various ways for economical handling in the manufacture of ice cream. The 10 per cent or more butterfat usually contained in ice cream is derived in part directly from milk. Additional fat is obtained from cream, sweet butter, salted butter, condensed whole milk, or butter oil. Milk is discussed elsewhere in detail (page 101). Since it contains butterfat in varying amounts, the percentage of fat should be definitely known in the calculation and purchase of milk. (See Testing for Fats, page 267.)

A definite relation exists between the fat and the solids-not-fat in milk. This is shown in Table XIV, page 102. When the percentage of fat in milk is known, the percentage of solids-not-fat can be seen at a glance.

**Cream.**—The greater portion of the fat in ice cream is derived from cream. The rich, creamy flavor is due to the amount of fat in the product. The definite percentage that will produce this desirable flavor is somewhat in question. It depends a great deal upon the amount and quality of the other ingredients present, as well as upon processing methods. Some experimental work has been done in an attempt to determine the consumer's preference. If this work is to be considered seriously, 10–12 per cent of fat will, under proper economical conditions, produce a cream equal to a 13–14 per cent one, but as soon as 15–16 per cent fat has been obtained, the flavor of the additional fat begins to stand out. In a strictly catering cream, fat contents above 16 per cent should be maintained. The quality of the cream and milk plays such an important part in the resultant flavor of the ice cream that every effort should be made to secure the best available cream. Clean-flavored cream with no

more than 0.15 per cent acid is the best possible source of butterfat for ice cream.

Cream should be purchased on the percentage of fat it contains. In addition to the fat, it contains, however, a certain amount of milk solids-not-fat, which must be taken into consideration in the calculation of the mix. Cream is undoubtedly the best source of fat and is to be preferred where conditions will permit. When cream is not available, the fat must be secured from some other source, usually sweet butter.

**Sweet Butter.**—Butter containing no salt is usually called sweet butter. It is usually a sour cream product, though it may be made from sweet cream. Salt brings out both good and bad flavors in butter. Without the presence of salt, off flavors are not so noticeable in the freshly frozen product. A period in storage, however, may bring them out in the ice cream.

Sweet butter as a source of fat is not objectionable, and its use should be permitted if the quality is right. There are times when sweet cream cannot be purchased and there are localities where the best quality cannot be obtained. Sweet butter, being less perishable than sweet cream, offers, therefore, a sanitary and economical source of fat. Since it varies greatly in composition, sweet butter should be purchased entirely on quality and fat content. Because of its large percentage of fat, usually from 83 to 85 per cent (and there have been cases where the fat content varied from 72-90 per cent), its composition must be checked carefully, both before purchase and before use. Besides fat, sweet butter contains a varying amount of moisture and approximately 1.5 per cent of other ingredients (curd, ash, lactose, and acid). It is generally purchased in the spring during the flush butter season, for use later in the year when the cream supply has decreased. It should be stored in the hardening room, which is near 0° F., to insure against deterioration.

**Butter Oil.**—Butter oil, as manufactured, is usually put up for the trade in 5-gal. cans. Prepared and sold in this way, it is usually too expensive for use in ice cream, though it does make, when properly combined and processed, a product of good grade. Butter oil can be prepared very satisfactorily, in cases of emergency, from good salted butter. The method is to place the butter in a double-jacketed kettle and add hot water. Heat is applied slowly until the temperature has reached 115° F. It is stirred and allowed to stand for a few minutes. As the butter oil is now floating on top, the curd, salt, and water may be drawn from the bottom. More hot water, not exceeding 140° F., is added and stirred in. When this rinse water is drawn off, a very satisfactory butter oil remains.

## CONDENSED PRODUCTS

It is necessary, as has already been stated, to build up or reinforce the milk solids-not-fat in ice cream in order to obtain a more palatable as well as a more nutritious product. This is done with some one of the following: condensed whole milk, condensed skim milk (either of these may be sweetened), or dried skim milk. Federal Standards require sweetened condensed milk, sweetened evaporated milk, and sweetened concentrated milk to contain 8 per cent milk fat and 28 per cent total milk solids.

**Sweetened Condensed Milk.**—Sweetened condensed milk contains all the constituents of fresh milk and, in addition, sucrose, which totals about 42 per cent in the finished product. For ice cream purposes, it is necessary to know the exact percentages in order to calculate a mix of the proper composition.

Hunziker[1] gives the following average composition of sweetened condensed milk, based upon a large number of analyses of the commercial brands:

| | | Per Cent |
|---|---|---|
| Water | | 26.5 |
| Proteins | 8.5 | |
| Fat | 9.0 | 32.6 |
| Milk sugar | 13.3 | |
| Ash | 1.8 | |
| Sucrose | | 40.9 |
| | | 100.0 |

Sweetened condensed milk is not used as frequently as either sweetened or unsweetened condensed skim. Sweetened condensed skim should be manufactured from properly pasteurized skim milk of good quality. The acidity of the skim milk before condensing should not exceed 0.18 per cent. Some plants make a practice of reducing the acidity to 0.18 per cent with sodium bicarbonate when necessary. This practice is not to be looked upon with favor, and undoubtedly is abused. Nevertheless, there are times, when, under the guidance of trained people, its use would be beneficial.

**Condensed Skim.**—Many of the larger ice cream manufacturers are finding it economical and advantageous to make their own condensed skim.

The equipment required consists of a vacuum pan with boilers of adequate capacity, a forewarmer, and cooling tanks. Less expensive apparatus for concentrating at atmospheric pressure is sometimes used.

[1] Hunziker, O. F., Condensed Milk and Milk Powder, 1920, p. 201.

Condensed skim is usually concentrated to 28–32 per cent milk solids, giving a yield of approximately $31\frac{1}{2}$ lbs. from each 100 lbs. of skim milk. The cost of manufacture is estimated at 25–30 cents per hundred lbs. of raw milk. The product sells for 9–11 cents per lb. of solids. Assuming a yield of $31\frac{1}{2}$ lbs., containing 32 per cent solids, with a manufacturing cost of 30 cents per hundred and a selling price of 10 cents per pound solids, there is a return of 71 cents per hundred for skim milk. Skim milk is usually condensed to 32 per cent solids. This allows for about as concentrated a product as possible without the formation of lactose crystals. Furthermore, in supplying the market, as little water should be shipped as possible. Condensed skim is quite perishable and should be given the same care and attention as pasteurized milk. It requires immediate cooling from the condensing pan and cold storage.

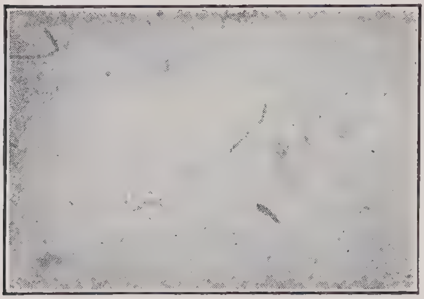


FIG. 33.—Showing Lactose Crystals in Plain Condensed Skim Milk. Dil. 0.

All of the condensed products should be bought on a solids basis, and, if fat is included, it should be given consideration also. Solids are the important consideration to the ice cream manufacturer. Many plants buy on the gallon basis, which is a satisfactory one if a reliable, standardized product can be obtained.

**Sweetened Condensed Skim Milk.**—There is a considerable demand for sweetened condensed skim milk by ice cream makers, confectioners, and bakers. The equipment required for manufacturing this product does not differ essentially from that used for the unsweetened condensed. Sweetened condensed should be cooled slowly, but immediately, upon being drawn from the condensing pan, to prevent crystallization of the sugar and the resulting sandiness. No harm will come from this sandiness if the entire mix is pasteurized, as it should be, and the entire barrel of the condensed product is used at once. Unless the portion left over is well mixed each time, the lactose content of that remaining at the bottom of the barrel is likely to exceed the maximum, especially if this part goes into a small mix. " Seeding " the sweetened condensed skim, when cooled to 70° F., with finely ground lactose crystals, holding for a few minutes, and then completing the cooling, will practically prevent the settling of lactose. If fine-mesh lactose is not available or is too expensive, crystallized lactose in the bottom of a barrel of sweetened

condensed could be used. It is best to grind these crystals with a colloid mill.

The market usually calls for a product containing 72 per cent of total solids, of which about 42–45 per cent is sucrose. The percentage of sugar in the finished product may be varied within certain limits, but must not be below the concentration required to prevent the growth of microörganisms.

When the finished milk sells for more per pound than the cost of the sugar, there is a tendency to increase the sugar content. On the other hand, if the value of milk solids is less than that of sugar, there is an opposite tendency.

Sweetened condensed, if properly made and stored, keeps almost indefinitely. It is usually shipped in paraffined oak barrels, of about 600 lbs. capacity. These barrels cost between three and four dollars each.

The cost of manufacturing will also be about the same as for the unsweetened product, plus the additional cost of the sugar, which is usually added at the rate of 18 lbs. of sugar to each hundred pounds of skim milk. It is usually considered profitable to make sweetened skim when the market price per pound equals or exceeds the cost of sugar per pound.

**Dry Skim Milk.**—Dry skim milk contains 97 per cent food solids. It is prepared in powder or flake form. Skim milk powder contains 38 per cent protein, usually little more than 50 per cent lactose (milk sugar), 8 per cent mineral matter, a trace of fat, and 3 per cent moisture. Cavanaugh, Dutcher, and Hall[2] found the quantity of vitamins A and B in skim-milk powder practically equal to that present in the milk from which it was made.

The value of the skim milk solids, or milk solids-not-fat, cannot be overestimated. In fact, in considering the value of dairy products, it is believed that the fat has been given a rating too far above the other solids in milk. The mineral matter, calcium, phosphates, and other salts are in a particularly desirable form for building bones and teeth and should therefore be adequately supplied to the growing child. Ice cream supplies in the most palatable form more of these constituents than does any other of the dairy products. Nutritional experts are rightly giving the mineral content of our diet more and more attention.

Dr. Sherman,[3] of Columbia University, says: "American dietaries are probably more often deficient in calcium than in any other chemical element." It is known that certain functions of the body are not always

[2] Industrial and Engineering Chemistry, Vol. 16, No. 10, p. 1070.

[3] Sherman, H. C., Food Products, p. 23. Macmillan Company, 1924.

rightly performed if the diet does not supply a proper balance between the calcium and phosphorus.

This source of milk solids-not-fat offers a safe supply for ice cream, and if the proper care in processing and selecting the powder is taken, a very good quality of ice cream can be manufactured—certainly a product far superior to one in which no additional solids have been added. Many small ice cream manufacturers are not adding additional skim-milk solids. This is a mistake and undoubtedly lessens the consumption of ice cream. Skim milk and additional solids in a more concentrated form can be economically utilized in ice cream along with cream and butter.

Dry skim milk is a relatively new product that is already used in large quantities by bakers, ice cream makers, and confectioners. War conditions resulted in over-production, which has for a time demoralized the market; but as the value of this product is better understood, there is no doubt that the steady growth of the industry will be resumed.

The powder selected should be soluble, of a light color, and free from burned particles.

The yield of powder will vary from 8 to 9½ lbs., depending on the solids in the milk, the efficiency of the process used in recovering the powder, and the amount of water left in the product.

**Superheated Condensed and Unsuperheated Condensed Skim.**—Superheating means the heating of the condensed skim in the pan with live steam, to 185° or 190° F. The process undoubtedly coagulates the albumin and, of course, as some steam is condensed, reduces the percentage of total solids. Tracy[4] studied the effect of superheated condensed skim in ice cream on the following properties: (1) viscosity, (2) yield, (3) texture and body, (4) resistance, (5) flavor, (6) heat resistance. Superheated condensed skim gave the ice cream mix more viscosity and approximately 10 per cent higher yield.

The samples of ice cream made from the superheated skim had heavier body and a smoother texture, and were more resistant to heat. Moreover, the superheated condensed gave the ice cream a cooked and undesirable flavor. The work done by the authors, paralleling the work of Tracy, leads to the general conclusion that superheating is not only valueless but, as a matter of fact, undesirable. Good skim milk, properly pasteurized (not exceeding 158° F.), drawn to the pan and condensed under 26 inches of vacuum, gives the best results.

[4] Tracy, P. H., Ice Cream Review, April, 1923.

## SUGARS

Sugars (all kinds) are one of the chief ingredients of ice cream. The content ranges from 15 to as high as 24 per cent of the finished mix. Sugars represent almost half of the total solids in ice cream as it is made to-day. When properly used, they play a three-fold part in the improvement of ice cream, namely, in palatability, texture, and food value. Obviously, without sugar, the ice cream would lack sweetness and palatability. Sugar improves the texture of ice cream by increasing the total solids. Any increase in solids in the mix smooths the body by a partial fixing of the free moisture. This is pointed out by Davis,[5] Dahlberg,[6] and others. As a source of fuel, sugar is extremely economical. At 6 cents a pound, it provides 100 calories of energy for one-third of a cent. At present, it furnishes about 13 per cent of all the energy obtained from food consumed by the people of the United States. The average per capita consumption for the United States is over 100 lbs. a year, or 2 lbs. a week. Sugar provides none of the nitrogenous material, mineral substances, or vitamins needed by the body; these are supplied by the other solids in ice cream.

Of all the foods, the sugars probably are the most soluble in water and, in addition, are highest in food value. For the most part, they are characterized by sweetness. There is, however, considerable variation in the sweetness of sugars. Those occurring commonly in ice cream belong to the saccharose group, having the composition $C_{12}H_{22}O_{11}$. The most important are sucrose (beet and cane sugar), lactose, and corn sugar (dextrose) $C_6H_{12}O_6$.

Cane sugar has in the past been used more than beet sugar. It has a specific gravity of 1.595. Sucrose is extremely soluble. Even cold water will hold in solution twice its weight of sugar. United States Standard sugar is white, containing at least 99.5 per cent sucrose. It often contains 99.9 per cent, and in commercial practice is rightly considered 100 per cent. Beet sugar is usually cheaper than cane. Turnbow and Spilman[7] found that beet sugar was equal to cane in the manufacture of ice cream, as far as flavor, body, and texture were concerned. Beet or cane sugar depressed the freezing point to the same extent; the time required for the ice cream to melt was equal for the same per cent, all other factors being equal. The Indiana Station has prepared a table showing the degree of depression of the freezing point by sucrose.

[5] Davis, L. M., Calif. Agr. Exp. Sta., Report, 1916, p. 48.

[6] Dahlberg, A. C., Tech. Bul. 111, New York Agr. Exp. Sta.

[7] Turnbow, G. D., and Spilman, H. A., unpublished data, Univ. of Calif. Agr. Exp. Sta.

TABLE VIII

Effect of Sucrose on Freezing Point

| Freezing Point, °C | Per Cent Sucrose | Per Cent Total Solids | Per Cent Serum Solids | Per Cent Fat |
|---|---|---|---|---|
| −2.0 | 12.0 | 33.4 | 12.2 | 8.3 |
| −2.4 | 14.3 | 35.1 | 11.8 | 8.0 |
| −2.7 | 15.8 | 36.3 | 11.6 | 7.9 |
| −3.0 | 17.5 | 36.4 | 11.3 | 7.7 |
| −3.6 | 19.2 | 39.2 | 11.1 | 7.5 |

Fig. 34.—Sucrose Crystals.

Since an increase of approximately 7 per cent in sucrose lowers the freezing point 1.6° C., it is natural to expect that the time required to freeze the mix, to the point where the brine is shut off, will be longer. This part of the freezing process requires approximately forty-five seconds longer for each 2 per cent increase in sugar. A cold brine (0 to −5° F.) is necessary for an ice cream especially high in sugar. Any substance that goes into true solution in the mix lowers the freezing

point. Likewise, it increases the viscosity (see Viscosity). Sucrose ferments with difficulty in concentrated solutions and has the power of retarding the growth of bacteria. It is used in ice cream mix at the rate of 12–15 per cent.

**Lactose** ($C_{12}H_{22}O_{11} + H_2O$): **Milk Sugar.**—This sugar comprises a little over 50 per cent of the solids-not-fat in milk. It affects the viscosity of the mix to some extent, and lowers the freezing point. There is usually less than 6 per cent of it in the mix. This sugar in limited amounts (6 parts sugar to 1 part cold water) is soluble in water. Its specific gravity is 1.525. It is high in food value, and recent investigators are claiming medicinal value for it. In the souring of milk, the S. Lactis and certain other microörganisms bring about lactic acid fermentation by transforming the lactose of the milk into lactic acid. Lactose depresses the freezing point, as is shown by Parfitt and Taylor[8] in the following table:

TABLE IX

Effect of Lactose on Freezing Point

| Freezing Point, ° C. | Per Cent Lactose | Per Cent Total Solids | Per Cent Serum Solids | Per Cent Fat |
|---|---|---|---|---|
| −2.0 | 6.2 | 33.4 | 12.2 | 8.3 |
| −2.2 | 9.2 | 35.4 | 14.8 | 8.0 |
| −2.4 | 10.9 | 36.8 | 16.6 | 7.9 |
| −2.7 | 12.7 | 37.1 | 18.3 | 7.7 |
| −3.2 | 15.6 | 40.1 | 21.0 | 7.4 |

The ice cream manufacturers, recognizing that an increase in solids in the mix gave a corresponding increase in quality in the finished cream, accordingly increased the solids, especially the milk solids-not-fat, until defects began to appear which are now called "sand."

A great deal of experimental work has been done by Bothell,[9] Zoller,[10] Purdue University Agricultural Experiment Station,[11]

[8] Parfitt and Taylor, Journal of Dairy Science, Vol. 8, pp. 230–7, May, 1925.

[9] Bothell, F. H., Proc. 5th Ann. Convention, Pacific Ice Cream Mfgrs. Assoc., Portland, Ore., pp. 121–125, 1920.

[10] Zoller, F. H., and Williams, O. E., Sandy crystals in ice cream, their separation and identification. Jour. of Agr. Res., Vol. 21, pp. 791–796, 1921.

[11] Purdue University Agr. Exp. Sta., 33d Ann. Rep., Lafayette, Ind., 1920.

Evans,[12] Williams,[13], Dahle,[14] Leighton and Peter,[15] and others. The cause of sandiness has been established beyond any doubt. The following extract is taken from the *Proceedings of the World's Dairy Congress*:[16]

Hallimond has given a most excellent exposition of the theories of crystallization, with especial reference to the supersaturation theories. He points out that there are three main principles which must be taken into account in a theory of crystallization:

"The first concerns the existence, below the ordinary solubility curve for each constituent, of a range of temperature and concentration within which crystallization is only initiated upon the introduction of a suitable nucleus. The second is that the rate of growth of a crystal at first increases as the temperature falls below that of equilibrium (saturation) and then diminishes when a certain degree of supercooling is exceeded. The third is that the redistribution of heat and of dissolved matter, consequent on and essential to solidification at the surface of a growing crystal, is governed by gradients of temperature and concentration which depend in their turn upon the respective coefficients of heat conductivity and of diffusion."[17]

The continued growth of a crystal is conditional on the maintenance of a supply of material by diffusion, and on the dissipation of the latent heat developed during crystallization.

According to Leighton and Peter,[18] the three factors determining the crystallizations of lactose or development of "sand" are (1) concentration, (2) temperature, and (3) seeding. They further state that, upon close examination of the solubility and freezing-point curves of lactose-water solutions, when the concentration is less than 11.9 parts of lactose to 100 parts of water, ice will separate before the solution becomes saturated with the sugar. Their own account of their observations follows:

This means that the unfrozen portion of the solution with lowering temperature then becomes more saturated with lactose. Theoretically, when the temperature of the cryohydric point is reached, ice and sugar should separate together; but we have shown that lactose is capable of forming highly supersaturated solutions, so in the absence of nuclei we

[12] Evans, R. D., Thesis for Master's Degree in Agricultural Biochemistry, University of Minnesota. (Unpublished.) 1922.

[13] Williams, O. E., Sandy ice cream. New York Produce Review, Vol. 53, pp. 878–884, March 1, 1922.

[14] Dahle, C. D., Watch for sand. Ice Cream Review, Vol. 6, pp. 22–4, 1923.

[15] Leighton, Alan, and Peter, P. N., Factors influencing the crystallization of lactose, Proc. World's Dairy Congress, Vol. 1, pp. 477–485, 1923.

[16] Vol. 1, p. 480, 1923.

[17] Hallimond, A. F., Jour. Iron and Steel Inst., Vol. 105, No. 1, pp. 359–379, 1922.

[18] World's Dairy Congress, Vol. 1, pp. 483–485, 1923.

might pass along the freezing-point curve, with a further separation of ice and a continued concentration of lactose, into the meta-stable area. We might even under suitable conditions pass through a supercryohydric point into the labile area without lactose separation. In this case it is quite probable that the whole mass would solidify without crystal formation, into an amorphous mass.

Freezing experiments upon lactose-water solutions covering a wide range of concentration show that it is actually possible, if nuclei are absent, to carry these solutions well into the labile state with the separation of ice alone. Lactose solutions of 10 parts of lactose to 100 of water may be frozen solid without the visible appearance of the lactose crystals. It has been found possible to freeze a solution containing 30 parts of lactose without the separation of lactose until a few minutes after freezing starts. In one instance, as judged by the temperature at which crystallization took place, we had a solution containing 70 parts of lactose to 100 of water. In a number of instances, even when the lactose crystals formed, they were so fine that they could be made to pass through a filter paper.

This brief exposition of the significance of the freezing-point and solubility curves serves to show us roughly the conditions which exist in ice cream, particularly if the solubility of lactose in the water of an ice cream mix is not markedly affected by the presence of the other constituents, and, as far as we know, it is not. A few solubility results are given in the following table:

TABLE X

Solubility of Lactose in an Ice Cream Mix Containing 12 Per Cent Fat, 10 Per Cent Milk solids-not-fat, 14 Per Cent Sugar (Sucrose) and 0.4 Per Cent Gelatin

| Temperature, ° C. | Parts of Lactose to 100 Parts of Water |
|---|---|
| 1 | 13.54 |
| 8 | 14.91 |
| 15 | 16.05 |

It is quite evident, then, that, provided there are no lactose crystals present in an ice cream mix to furnish nuclei for crystal growth, ice cream may be carried well into the labile state. It will also be true that the tendency of the lactose to crystallize after freezing will be small as long as sufficiently low temperatures are maintained. This is in keeping with Hallimond's statement that the tendency to crystallize is lessened when a certain degree of supercooling is exceeded. If crystallization has taken place, the crystals may be so fine as to escape detection, and they

will, of course, not tend to increase in size if low temperatures are maintained. With rising temperatures, as the melting point is approached the tendency to lactose crystallization in either case will increase. We thus see why concentration and temperature—the same factors which largely control the separation of the milk sugar from ordinary solution—are factors in governing the development of sand in ice cream.

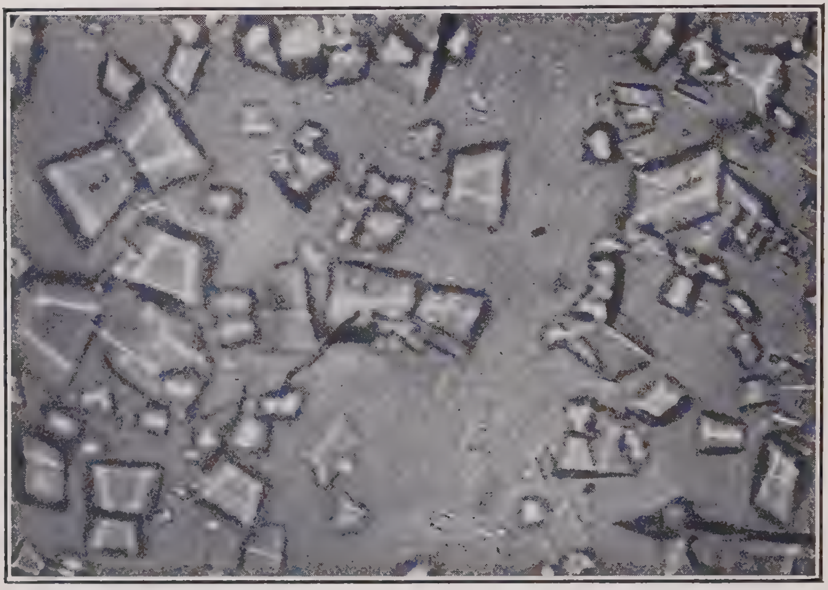


Fig. 35.—Sweetened Condensed Skim Milk. No Effort Was Made to Control the Size of the Lactose Crystals. Dil. 0.

So far we have called attention to the effect of temperature, concentration, and seeding on lactose crystallization from aqueous solutions, endeavoring to show the bearing of this on the separation of milk sugar from concentrated milk and ice cream.

When we are dealing with milk solutions, however, the conditions are not so simple as with pure aqueous solutions. The viscosity becomes a factor in controlling the rate of diffusion of the lactose to the growing crystal. The preliminary treatment of the milk may have been such as not only to affect viscosity, but to produce nuclei favoring crystallization. For example, we have already shown that the forewarming of a milk can produce nuclei in the form of insoluble salts which may induce lactose crystallization in both meta-stable and labile areas, and it is well known that forewarming markedly affects the viscosity of both evaporated and condensed milks.

Lactose does not usually give trouble in ice cream unless the concentration is high (that corresponding to a milk solids-not-fat concentration of about 12 per cent).

The defect of sandiness is characterized by gritty, sand-like substances in the ice cream. The crystals are not readily soluble, as is the case with water crystals (though neither are desirable) and they make the ice cream unpalatable and unsalable.

Evans studied lactose concentrations at 0° C. His results are expressed in Table XI.

TABLE XI

CONCENTRATIONS OF LACTOSE AT 0° C. AT DIFFERENT AGES

| Original Lactose Concentration of Solution | Lactose Concentration after 48 Hours of Freezing | Lactose Concentration after 96 Hours of Freezing | Lactose Concentration after 1 to 4 Hours of Freezing |
|---|---|---|---|
| Per cent | Per cent | Per cent | Per cent |
| 5 | 4.99 | 4.77 | 4.92 |
| 7.5 | 7.49 | 6.86 | 7.29 |
| 10 | 9.68 | 8.66 | 9.41 |
| 12.5 | 11.49 | 10.27 | 12.01 |
| 15 | 13.25 | 12.17 | 12.45 |
| 17.5 | 13.60 | 13.40 | 13.84 |

Authorities agree that sugars—sucrose, dextrose, glucose, and cane sugar—as well as gelatin and the enzymes sometimes used (see Aging of Mix), have no effect on preventing lactose crystallization.

It is impossible to state a definite percentage of milk solids-not-fat at which sand crystals will appear. The percentage of milk solids-not-fat must have a definite relation to the free moisture. Dahle states that the percentage of lactose in the water-free state cannot exceed 8.7 per cent, based upon a total solids content of 36.5 per cent.

Variation in the holding temperature of the ice cream is conducive to lactose crystallization. The more constant the temperature, the less likely is the formation of crystals. Ice cream held in dealers' ice-and-salt cabinets, if the mix is not properly constructed, offers the greatest possibilities for the formation of crystals. Williams[19] illustrates by the following table the effect of a variation of temperature on the occurrence of sand.

[19] Williams, O. E., Sandy ice cream. New York Produce Review, Vol. 53, pp. 878–884, March 1, 1922.

TABLE XII

INFLUENCE OF HOLDING TEMPERATURE ON THE OCCURRENCE OF SANDINESS *

| Mix Number | Time until Sandiness Occurred | | Mix Number | Time until Sandiness Occurred | |
|---|---|---|---|---|---|
| | In hardening room | In cabinet | | In hardening room | In cabinet |
| | Days | Days | | Days | Days |
| 1 | 19 | 8 | 6 | 21 | 10 |
| 2 | 7 | 10 | 7 | 26 | 10 |
| 3 | 0 | 7 | 8 | 11 | 7 |
| 4 | 12 | 7 | 9 | 0 | 6 |
| 5 | 10 | 5 | 10 | 15 | 7 |

* World's Dairy Congress, Vol. 1, p. 509, 1923.

The hardening-room temperatures varied from −10° F. to +10° F. Cabinet temperatures varied from +5° F. to +20° F. It must be pointed out that the more constant the temperature, even though it be higher than recommended, the less likely is the formation of lactose crystals. The higher the holding temperature, the greater the possibilities of sandy ice cream, all other things being equal.

**Corn Sugar or Dextrose.**—Corn sugar may be considerea a by-product of the corn industry. In recent years its manufacture has been so perfected that now it is supplied to the ice cream industry at a price which may justify its use to some extent. It has only about 60 per cent of the sweetening power of sucrose. Any increase in solids, as before mentioned, tends to produce a smooth ice cream. It is impracticable to increase the percentage of butterfat; gelatin should be kept within the correct percentage for the purpose for which it is intended, i.e., stabilization; milk solids-not-fat are limited on account of lactose crystallization; sucrose cannot be increased because it makes the ice cream too sweet. Therefore, dextrose offers a possibility of increasing the total solids without any of the above defects. It does lower the freezing point, so that more refrigeration is required. In addition, being an invert sugar, it can be used only in limited amounts because of its effect upon the body and texture of the ice cream.

Cerelose increases the viscosity and depresses the freezing point, the latter even more than the same amount of sucrose. It absorbs moisture

TABLE XIII

EFFECT OF CORN SUGAR (CERELOSE) UPON FREEZING POINT *

| Mix Number | Per Cent Fat | Per Cent M.S., N.F. | Per Cent Sugar | Per Cent Gelatin | Per Cent T.S. | Freezing Point, ° F. | Difference Due to Sugar | Temp. of Mix When Brine Was Shut Off, ° F. | Time to Obtain 100 Per Cent Overrun |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 10 | 12 | .35 | 34.34 | 28.094 | .000 | 26.06 | 7′ |
| 2 | 12 | 10 | 14 | .35 | 36.35 | 27.671 | .413 | 25.34 | 7′45″ |
| 3 | 12 | 10 | 15 | .35 | 37.35 | 27.491 | .603 | 25.07 | 7′50″ |
| 4 | 12 | 10 | 16 | .35 | 38.35 | 27.140 | .954 | 24.44 | 7′45″ |

* Dahle, C. D., Filling up the gaps in freezing data, Ice Cream Trade Journal, p. 63, March, 1926.

quite readily, and is very soluble. It contains around 90 per cent solids and .06 per cent inorganic matter. Work done by the authors indicates that not more than 20–25 per cent of sucrose may be replaced by cerelose. Ice cream containing cerelose does not stand up as well as does that made from sucrose. Neither sugar will prevent sandiness. As a matter of fact, if large quantities of cerelose are used, and if the mix already contains a percentage of milk solids-not-fat naturally conducive to the formation of sand, there is a greater probability of sandiness, since there is less free moisture available to keep the lactose in solution. Cerelose, being very soluble, naturally absorbs moisture enough for its solution. Overrun can be obtained equally as readily with cerelose as with sucrose, if a little colder brine is used.

**Invert Sugars.**—Several invert sugars and sugar substitutes were used during the war, before ice cream was recognized as a food. The public is realizing more and more, however, the highly nutritious character of properly made ice cream; it is doubtful, therefore, that any substitute for the sugars already discussed in this chapter will be again required.

**Structure of Milk.**—If the ingredients of an ice cream are properly combined, dairy products constitute from 81 to 85 per cent of the material from which it is derived. This comparatively large percentage comes either from milk or from products which have been manufactured from milk. It is of prime importance, therefore, that the manufacturer have a clear conception of this vital constituent of the product he makes. Table XIV pictures quite clearly the complexity of milk.

TABLE XIV

COMPOSITION OF MILK

| | | | | | | |
|---|---|---|---|---|---|---|
| Milk..100.0 | Butterfat... 3.7 | Laurin<br>Olein<br>Palmitin<br>Stearin<br>Myristin | Glycerides of insoluble and non-volatile acids. | 3.4 | Fat 3.7 | Total solids 12.6 |
| | | Butyrin<br>Caproin<br>Caprylin<br>Caprin | Glycerides of soluble and volatile acids. | .3 | | |
| | Milk serum. 96.3 | Casein....... 2.75<br>Lactalbumin. .60<br>Lactoglobulin .20 | Containing nitrogen... | 3.55 | Solids-not-fat 8.90 | |
| | | Milk sugar.....................<br>(Lactose) | | 4.50 | | |
| | | Citric acid..................... | | .15 | | |
| | | Potassium oxide<br>Sodium oxide<br>Calcium oxide<br>Magnesium oxide<br>Iron oxide<br>Sulphur trioxide<br>Phosphorus pentoxide<br>Chlorine | Ash....... | 0.70 | | |
| | | Water..................................... | | | | 87.4 |
| | | | | | | 100.0 |

Milk, according to Palmer,[20] consists essentially of a microscopic dispersion of fat in an aqueous plasma containing molecularly dispersed lactose, certain mineral salts, colloidally dispersed proteins, in which calcium caseinate and lactalbumin predominate, and a colloidally dispersed calsium phosphate,[21] $Ca_2H_2(PO_4)_2$. The important colloids of milk, therefore, are calcium caseinate, lactalbumin, and neutral dicalcium phosphate. It is not likely that the colloidally dispersed lactoglobulin, an alcohol-soluble protein, plays a rôle of any importance in the physical or chemical structure of normal cow's milk. The true casein content of normal cow's milk varies from 2.25 to 2.75 per cent, depending, of course, upon the breed and various other factors which are known to influence the solids in milk. Lactalbumin varies between 0.5 and 0.7 per cent, while the calcium phosphate comprises slightly less

[20] Palmer, Ind. and Eng. Chem., Vol. 16, p. 631, 1924; also Vol. 2, Proc. World's Dairy Congress, p. 1157, 1923.

[21] Condition of casein and salts in milk, N. Y. Tech. Bul. 39, pp. 8–15; and Jour. of Bio. Chem. Vol. 20, p. 135–152, 1915.

than 0.2 of 1 per cent of the milk. Inasmuch as pure iso-electric casein ($p$H 4.7) will disperse in pure water to the extent of only 0.01 per cent, it has been assumed by some that the high percentage of casein in milk is due to the protective action of the lactalbumin. It is possible completely to filter out, the use of ultra-filters of relatively large porosity, the calcium caseinate and calcium phosphate that are found normally in colloidal dispersion in milk.

In Robertson's[22] opinion, the largest possible molecules in casein would not be of sufficient diameter to scatter light particles and cause the opalescence of casein solutions, particularly those of calcium caseinates. Osborne and Wakeman[23] seem to have shown definitely that the colloidally dispersed lactalbumin of cow's milk exists uncombined with a base. In its highly hydrated form, it makes an almost water-clear solution when freed from the casein and can be easily dehydrated and coagulated by heat. Palmer indicates that the lactalbumin is in a very highly dispersed state, probably more so than the other two important colloids of the plasma.

The factors that determine the stability of the colloids in ice cream have not been thoroughly studied. Undoubtedly, a knowledge of these underlying factors would aid materially in stabilizing the structure of an ice cream and thus constitute one step in controlling the weight per gallon.

The gold number, as usually referred to, is not applicable in the case of casein. Zsigmondy has assigned a gold number of 0.01 to casein. This was determined for an ammonium sol. Ammonium caseinate does not exist in cow's milk.

It is very possible that lactalbumin plays a far more important part in stabilizing than it has been given credit for. A thorough study should be made of the calcium caseinates and the calcium phosphates in stabilizing colloidal casein compounds. The action of salts on colloids and their effect on the stabilizing of the emulsoid sols is quite well known. Inorganic ions exist abundantly in milk and, therefore, have a stabilizing effect upon the colloids in an ice cream mix.

Milk not only represents a very complex colloidal solution, but in addition is one of the few examples of a natural biological emulsion. In addition to these complexities, certain constituents in milk exist in true solution. Ice cream probably presents more unsolved problems of a colloidal nature than does any other dairy product. Its physiological

[22] Robertson, Physical Chemistry of Proteins, p. 343, Univ. of Calif. Printing Office, 1918. Reprint from Longmans, Green & Co.

[23] Osborne and Wakeman, The proteins of cow's milk, Jour. of Bio. Chem., Vol. 33, No. 7, 1918.

make-up is more complex than that of any other dairy product. A partial insight into its complexity is given in the following table:

TABLE XV

PHYSIOLOGICAL ASPECT OF AN ICE CREAM MIX

| True solution in milk serum | Partial solution and partial suspension or colloidal solution | Complete suspension or colloidal solution |
|---|---|---|
| Lactic acid | Albumin | Fat |
| Citric acid | Gelatin | Casein |
| Potassium | Calcium | Eggs (if used) |
| Sodium | Magnesium | Fruits |
| Chlorine | Eggs (if used) | Nuts |
| Lactose | | |
| Sucrose (beet or cane) | | |
| Corn sugar (if used) | | |
| Flavors | | |

The problem of stabilizing viscosity to produce an ice cream that is palatable and nutritious offers a large field for research. Factors influencing crystallization, or the control of crystallization, are probably tied up with the colloids. Most investigators have thought viscosity a measure of these factors. Undoubtedly, there are other factors or constituents which function with colloids and which do more to determine the palatability, texture, body, and stabilization of ice cream than does viscosity. Possibly, as Dr. Rahn[24] has pointed out, the important factor may be a new compound, which he has called "foam compound." Viscosity and its determination will be discussed later.

Many attempts have been made by different investigators to prevent crystallization of lactose by the use of different colloids in varying amount and quality. Thus far they have failed, at least insofar as prevention of lactose crystallization through the use of a protective colloid is concerned.

**Butterfat.**—Butterfat has no influence upon the freezing point of ice cream, as shown by Dahle.[25]

Practically every state has a butterfat standard for ice cream, and the quality of this product has come to be judged largely by the amount of fat it contains. It should not be so judged, because other constituents in ice cream are just as essential in rendering it palatable and nutritious. Of all the single constituents of ice cream, however, fat is the highest in food value.

[24] Rahn, Otto, Series of lectures presented at Dairy Industry Short Course, Feb., 1926, University of California.

[25] Dahle, C. D., Ice Cream Trade Journal, March, 1926, p. 63.

TABLE XVI

EFFECT OF BUTTERFAT ON FREEZING POINT OF ICE CREAM

| Per Cent Fat | Per Cent M.S.N.F. | Per Cent Sugar | Per Cent Gelatin | Total Solids | Per Cent Water | Freezing Point, ° F. |
|---|---|---|---|---|---|---|
| 8 | 10 | 15 | .35 | 33.35 | 66.65 | 27.590 |
| 10 | 10 | 15 | .35 | 35.35 | 64.65 | 27.581 |
| 12 | 10 | 15 | .35 | 37.35 | 62.65 | 27.554 |
| 14 | 10 | 15 | .35 | 39.35 | 60.65 | 27.473 |

The fat in milk exists in the form of an emulsion and has only slight stability. Upon standing, it soon rises to the surface. It is usually separated from the milk by centrifugal force, for the production of cream. The density of fat in liquid form is 0.92. The globules in milk exist in clusters and have a range in diameter of approximately 0.01–0.0016 mm. Fat is usually the basis for establishing the price of milk and cream, since it is the most valuable single constituent.

Butterfat is made up of nine separate and distinct fats. The percentage of each of these varies with the individual animals, breed, age, length of lactation period, and many other factors. Butterfat represents, as a rule, only 8–14 per cent of ice cream and does not influence the quality of this product to such a great extent as it does that of butter, of which it forms at least 80 per cent. The fats in butterfat exist normally in the form of a chemical combination of glycerol (glycerin). They differ from all other fats in that they contain compounds of glycerides, built up probably from fatty acids of low molecular weight. They are grouped into two general classes, volatile and non-volatile. The volatile fats are often referred to as soluble, and the non-volatile fats as insoluble. Hunziker[26] says that in reality none of the fats are soluble or volatile, but that the fatty acids of some of the fats of glycerides, as the result of the decomposition of the respective glycerides, become separated from their base, the glycerol, and become soluble and volatile. Of the total milk fat, about 8–12 per cent yields volatile and soluble fatty acids, while the remainder is insoluble and non-volatile. Butterfat has a peculiar property of absorbing flavors, whether desirable or undesirable. These are transmitted to the ice cream and are often the cause of off flavors. Only the best quality of fat, therefore, should be used in ice cream. Its effect upon texture and body will be discussed in a later chapter.

[26] Hunziker, O. F., The Butter Industry, p. 533.

There has been much discussion and disagreement among investigators as to whether or not butterfat globules in normal milk are surrounded by a film. This makes but little difference in the manufacture of ice cream, since the fat so used has been concentrated in various forms by the method of processing and by the addition of other material with the result that it has undergone a physical change. Undoubtedly, surface tension plays a very important part at this point. The authors and certain other investigators are of the opinion that the butterfat globules form a nucleus upon which the serum solids and added colloids are adsorbed.

A. C. Dahlberg[27] points out that milk fat prevents the formation of large ice crystals, by mechanical obstruction. He demonstrated this by the use of an ice cream containing 30 per cent butterfat, 0.3 per cent protein, and 13 per cent sugar, and states that the cream remained smooth in the hardening room. He also states in the same publication that the milk fat, when combined with the milk solids-not-fat, had a greater combined effect on the texture than either alone. It required less gelatin to obtain the same results where the solids were increased. He explains this on the assumption that the water which was withheld from the gelatin was frozen into small ice crystals and that this water never actually contained any gelatin. This indicates that the higher the solids in ice cream, the greater the amount of water absorbed and adsorbed. It is believed that when this amount is large the product is more stable and has a smoother texture.

**Effect of Butterfat on Viscosity.**—Butterfat affects viscosity to some extent, since a certain amount of water is adsorbed in the mix, and the viscosity of fat is greater than that of the water replaced; this is shown by the following table.[28]

TABLE XVII

EFFECT OF BUTTERFAT ON VISCOSITY *

| Sample | Per Cent Fat | Per Cent Gelatin | Viscosity Poise |
|---|---|---|---|
| 1 | 3.1 | None | 8.1 |
| 2 | 7.6 | None | 13.6 |
| 3 | 10.8 | None | 27.2 |

* Certified 34 gauge wire

[27] Dahlberg, A. C., Tech. Bul. 111, N. Y. Agr. Exp. Sta., 1925.

[28] Turnbow, G. D., and Milner, F. W., Some physical and chemical factors affecting ice cream mixes, Minutes of the Joint Conv. Calif. & S. W. S. Ice Cream Mfrs. Ass'n, p. 52, 1926.

Nelson and Reid,[29] repeating the work of other investigators, found that increasing the fat increased the ease of obtaining yield, and that with each 2 per cent increase in fat, the finished cream had more resistance to penetration. Their work includes a range of fat from 6 to 25 per cent. Everything else being equal, the yield increased with each increase in fat up to 10 per cent. From 10 to 25 per cent, the yield decreased. There are, however, many other factors contributing their influence to this decrease. Too much viscosity is just as undesirable as not enough. An increase in fat fixes more serum solids. Nelson and Reid state that fat has a greater influence on the yield than does the viscosity of the mixture.

TABLE XVIII

EFFECT OF DIFFERENT PERCENTAGES OF BUTTERFAT ON THE HARDNESS OF ICE CREAM *

| Fat Content | Hours Tempered | Temp. of Ice Cream | Size of Needle, Mm. | Penetration in Millimeters | | | |
|---|---|---|---|---|---|---|---|
| | | | | Center | End | End | Average |
| Per Cent | | Degrees C. | | | | | |
| 4 | 7½ | −10.4 | 6.35 | 23.0 | 24.0 | 25.0 | 24.0 |
| 6 | 7½ | −10.5 | 6.35 | 25.0 | 26.0 | 26.0 | 25.7 |
| 8 | 7½ | −10.0 | 6.35 | 25.0 | 26.0 | 26.0 | 25.7 |
| 10 | 7½ | −10.2 | 6.35 | 24.0 | 25.0 | 25.0 | 24.7 |
| 12 | 7½ | −10.2 | 6.35 | 23.5 | 23.5 | 23.5 | 23.5 |
| 14 | 7½ | − 9.7 | 6.35 | 26.0 | 25.0 | 25.0 | 25.3 |
| 16 | 7½ | −10.1 | 6.35 | 25.2 | 24.2 | 24.0 | 24.5 |
| 18 | 7½ | −10.0 | 6.35 | 22.5 | 23.0 | 23.5 | 23.4 |
| 20 | 7½ | −10.3 | 6.35 | 23.0 | 23.7 | 23.7 | 23.5 |
| 25 | 7½ | − 9.0 | 6.35 | 24.5 | 26.0 | 25.7 | 25.4 |

* Nelson and Reid, Res. Bul. 70, Missouri Agr. Exp. Sta., 1924.

Nelson and Reid found also that no direct relationship existed between the fat content of the ice cream and its hardness. Any apparent variation was due to experimental error.

The melting resistance was increased with each additional increment of fat. This work indicated that 10–12 per cent butterfat gave a more desirable flavor and a very desirable texture. The ice cream was smooth and mellow.

[29] Nelson, D. H., and Reid, Wm. E., Res. Bul. 70, Missouri Agr. Exp. Sta., 1924.

TABLE XIX

Effect of Different Percentages of Butterfat on the Specific Gravity and the Yield of the Ice Cream Mixture *

| Fat Content | Specific Gravity at 15° C. | Weight of Mixture | Weight of Ice Cream | Per Cent Yield |
|---|---|---|---|---|
| Per Cent | | | | |
| 4 | 1.104 | 1432 | 755 | 89.7 |
| 6 | 1.102 | 1437 | 757 | 89.8 |
| 8 | 1.098 | 1440 | 755 | 90.7 |
| 10 | 1.093 | 1436 | 748 | 92.0 |
| 12 | 1.088 | 1434 | 749 | 91.5 |
| 14 | 1.085 | 1428 | 747 | 91.2 |
| 16 | 1.081 | 1422 | 744 | 91.1 |
| 18 | 1.076 | 1414 | 741 | 90.8 |
| 20 | 1.071 | 1387 | 735 | 88.7 |
| 25 | 1.066 | 1372 | 740 | 85.4 |

* Nelson and Reid, Res. Bul. 70, Missouri Agr. Exp. Sta., 1924.

**Proteins in Milk.**—Casein from normal cow's milk is white, amorphous, and without taste or odor, and has a specific gravity of 1.259. It is of high food value and lends itself readily to the absorption of moisture. This tendency helps to fix the water in ice cream mixes, thus producing better texture. The amount of casein in normal mixed cow's milk varies, according to L. L. Van Slyke[30] from 1.8 to over 3 per cent, while in individual animals it may vary from 1.5 to 4.5 per cent. The amount of casein and other proteins in milk is in very constant relative proportions.

Casein is a complex chemical compound, belonging to a special subdivision of the phospho-proteins. Knowledge of the proteins at the present time permits an expression of the composition of proteins in the percentage of the different amino acids formed upon the hydrolysis of the protein.

The products of decomposition of casein have been given considerable study. Table XX lists the products of decomposition of the three most important proteins in ice cream.

It will be noted in the table above that not all the products of decomposition of the proteins in ice cream are accounted for, there being approximately 90 per cent of casein and gelatin accounted for and only

[30] Van Slyke, L. L., World's Dairy Congress, p. 1145, 1923.

TABLE XX *

PRODUCTS OF DECOMPOSITION OF THREE PROTEINS IN ICE CREAM

| | Casein | Lactalbumin | Gelatin |
|---|---|---|---|
| Glycocoll | 0.45 | 0.37 | 25.5 |
| Alanine | 1.85 | 2.41 | 8.7 |
| Valine | 7.93 | 3.30 | 0.0 |
| Leucine | 9.70 | 14.30 | 7.1 |
| Proline | 7.63 | 3.76 | 9.5 |
| Oxyproline | 0.23 | (?) | 14.1 |
| Phenylalamine | 3.88 | 1.25 | 1.4 |
| Glutaminic acid | 21.77 | 12.89 | 5.8 |
| Oxyglutaminic acid | 10.50 | 10.00 | 0.0 |
| Aspartic acid | 4.10 | 9.30 | 3.5 |
| Serine | 0.50 | 1.76 | 0.4 |
| Tyrosine | 4.50 | 1.95 | 0.01 |
| Cystine | (?) | 1.73 | (?) |
| Histidine | 2.50 | 2.61 | 0.9 |
| Arginine | 3.81 | 3.47 | 8.2 |
| Lysine | 7.62 | 9.87 | 5.9 |
| Tryptophane | 1.50 | 2.40 | 0.0 |
| Ammonia | 1.61 | 1.31 | 0.4 |
| Total | 90.17 | 83.41 | 91.31 |

* World's Dairy Congress, Vol. 1, p. 441, 1923. Lafayette Mendel.

83.4 per cent of lactalbumin. It is possible that when these missing compounds are found, there will be sufficient information to complete the stabilization of an ice cream mix. It may be that the "foam compound" referred to is involved with these proteins. Casein dissolves quite readily in moderately dilute acids, especially at a high temperature, forming soluble compounds which may be a combination of acid with a casein molecule or hydrolytic products, depending upon the concentration of the acid and the temperature at which the action takes place. A very small amount of dilute acid tends to precipitate casein. Even though the acidity is too slight to be noticeable, it is undesirable and tends to produce a rough-textured ice cream with large air cells. Acidity in the ice cream mix is discussed in detail in another part of this book.

**Milk Solids-not-fat.**—The milk solids-not-fat play a very important part in the production of ideal ice cream. They are high in food value and reasonable in price. The use of larger quantities would be highly desirable from the dairyman's point of view, inasmuch as skim-milk is

largely a surplus. Work done by the authors indicates that any increase in milk solids-not-fat produces an ice cream, all other things being constant, with greater palatability, a more compact, uniform texture, and generally greater stability. Dahlberg[31] points out that milk solids-not-fat in the absence of fat did little to produce a smooth ice cream. Large ice crystals were formed. Fat alone was better than milk solids-not-fat. The best results were obtainable only when the two were present.

Work done by the authors, in which exceedingly high percentages of milk solids-not-fat were used and the fat kept constant (10.50 per cent) gave an excellent ice cream. A smaller loss was noted in dipping. Less gelatin was required for each increase in milk solids-not-fat. Undoubtedly, this was due to the smaller amount of available water that could disperse the gelatin.

The freezing point of the ice cream is lowered to some extent with each increase of milk solids-not-fat, because of the increased lactose in true solution, and the small amount of salts that go into solution. The two most important proteins, casein and lactalbumin, are in colloidal solution but do not affect the freezing point of the ice cream mix.

Considerable work has been done by various investigators (Dahle, Reid, Parfitt, and others) on the depression of the freezing point by the various solids. Table XXI, by Dahle,[32] shows the effect of all the milk solids-not-fat, while Table IX shows the effect of lactose alone, clearly pointing out that the proteins have no effect.

TABLE XXI

EFFECT OF INCREASING MILK SOLIDS NOT FAT ON FREEZING POINT OF MIX

| Mix Number | Per Cent Fat | Per Cent M.S. N.F. | Per Cent Sugar | Per Cent Gelatin | Per Cent T.S. | Per Cent Water | Freezing Point, °F. | Depression Due to M.S. N.F. °F. |
|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 8 | 15 | .35 | 35.35 | 64.65 | 27.986 | .000 |
| 2 | 12 | 10 | 15 | .35 | 37.35 | 62.65 | 27.554 | .342 |
| 3 | 12 | 12 | 15 | .35 | 39.35 | 60.65 | 27.176 | .720 |
| 4 | 12 | 14 | 15 | .35 | 41.35 | 58.65 | 26.222 | 1.674 |

[31] Dahlberg, A. C., Tech. Bul. No. 111, N. Y. Agr. Exp. Sta.

[32] Dahle, C. D., Filling up the gaps in freezing data, Ice Cream Trade Journal, March, 1926, p. 63.

**Lactalbumin.**—There are other proteins in milk besides casein and lactalbumin. However, from the data available, there is no indication that they play any important part in the manufacture of ice cream. Lactalbumin, which is very similar to egg albumin, exists in milk in small quantities. It aids in building up the total solids and is high in food value. It is precipitated by heat, but at the ordinary pasteurization temperature of an ice cream mix it is affected little, if at all. In the manufacture of condensed whole or skim-milk for use in the manufacture of ice cream, the lactalbumin is not affected unless high temperatures are used. The use of superheated condensed skim-milk will be discussed under another heading.

## EGGS

Eggs are sometimes used in the manufacture of commercial ice cream, the fresh, whole egg being used in some cases, and in others the yolk alone, either fresh or powdered. In fancy or catering cream, good fresh eggs are almost universally used. French vanilla (a parfait) should always contain eggs of the best quality. The average weight of a hen's egg is 60 grams. A dozen eggs weigh 1.58 lbs. The size and grade vary so much that this figure can only be an estimate. The average composition of the edible portion of the hen's egg, according to Leach,[33] is as follows: water, 73.7 per cent; proteins, 14.8 per cent; fat, 10.5 per cent; salts (mineral matter), 1.0 per cent.

The egg white (albumin) has a specific gravity of 1.045, and always gives an alkaline reaction. The yolk is much more complex than the white, and by far more yolks are used in ice cream than whites. Eggs are emulsifying agents and undoubtedly were originally added for this purpose. The powdered egg yolk that is used in ice cream (plain or fancy), is largely imported from the Orient where it is usually prepared by American or English companies under regulations. Naturally, there are various grades, and probably the dissatisfaction expressed by some manufacturers is due to the use of a poor grade. Obviously, only the best grade should be used. The price of the powdered yolk is usually very close to that of butterfat. The powder contains 50–60 per cent egg fat and 2–5 per cent moisture and is used on the average at the rate of 0.5 of one per cent in the mix. Manufacturers use eggs more often in fancy cream than in plain cream, and a great number of them buy shell eggs. Eggs should either be prepared by heating slowly to 145° F. in the presence of cream, milk, or mix, in the proportion of one dozen eggs to one quart of milk or cream; or else should be added to the mix cold, and heated in

[33] Leach, A. E., Food Inspection and Analysis, p. 268. John Wiley & Sons, 1920.

the vat while the mix is being pasteurized. The heating eliminates any raw egg flavor. The eggs should be homogenized with the rest of the mix. Exceptions may be made to this in the preparation of small amounts for special orders. About 6 dozen yolks are required to make 1 lb. of dehydrated yolk. Ice cream containing eggs, when drawn from the freezer, has a smooth, velvety appearance. The texture of the ice cream when hardened may not be smooth, however, if the composition of the original mix is incorrect. Mix containing the proper amount of eggs generally whips faster than one of the same composition but lacking in eggs. The salts present in eggs may have a bearing upon the whipping ability of the mix. Ordinarily, however, the benefit derived from the use of the ordinary amounts of eggs in ice cream is not sufficient to justify their use commercially. If eggs are to be of any benefit to ice cream, at least 5–10 dozen of U. S. Extras or their equal must be used in 100 lbs. of mix. The cost of such an amount of eggs prohibits the manufacturer from selling his product at the price ordinarily prevailing for plain ice cream. Unfortunately, few of the states have any standard for the amount of eggs that must be used in ice cream, if the product is to be labeled "Made with eggs."

TABLE XXII

United States Retail Grades for Eggs

| Minimum Percentage | U. S. Specials * | | U. S. Extras † | | U. S. Standards ‡ | | U. S. Trades § | |
|---|---|---|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 1 | No. 2 | No. 1 | No. 2 | No. 1 | No. 2 |
| | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent |
| U. S. Specials | 80 | 70 | ....... | ....... | ....... | ....... | ....... | ....... |
| U. S. Extras or better | 10 | 20 | 80 | 70 | ....... | ....... | ....... | ....... |
| U. S. Standards or better | Balance | Balance | Balance | Balance | 80 | 70 | ....... | ....... |
| U. S. Trades or better | ....... | ....... | ....... | ....... | Balance | Balance | 80 | 70 |
| Tolerance or Maximum allowance per case: U. S. Checks | Dozen 10/12 | Dozen 10/12 | Dozen 1 | Dozen 1 | Dozen 1–2/12 | Dozen 1–2/12 | Dozen 1–6/12 | Dozen 1–6/12 |
| Stained or slightly dirty U. S. Standard Dirties | 8/12 | 8/12 | 8/12 | 8/12 | 1–4/12 | 1–6/12 | Balance | Balance |
| Stained or Dirty U. S. Trade Dirties | ....... | ....... | ....... | ....... | ....... | ....... | 1–6/12 | 3 |

* Uniform in size.
† Reasonably uniform in size.
‡ May be variable in size.
§ May be greatly variable in size.

Weight requirements for the buying grades are specified.

Weight requirements for the wholesale grades will be such as are established by the wholesale egg trade for trading purposes. For the retail grades, the following weights are proposed:

| Size | Minimum Average Weight per Dozen | Minimum Weight Requirement for Individual Eggs |
|---|---|---|
| | Ounces | Ounces |
| Large.......... | 24 | 22 (1.833)* |
| Medium........ | $20\frac{1}{2}$ | 19 (1.533)† |
| Small........... | 17 | 15 (1.250)‡ |

* This is interpreted to mean that no single egg can weigh less than 1.833 oz.
† This is interpreted to mean that no single egg can weigh less than 1.533 oz.
‡ This is interpreted to mean that no single egg can weigh less than 1.250 oz.

Uniformity in Size of Eggs Required in the United States Wholesale and Retail Grades

TABLE XXIII

UNITED STATES BUYING GRADES FOR EGGS

MINIMUM REQUIREMENTS

| U. S. Extras | U. S. Standards | U. S. Trades | U. S. Check * |
|---|---|---|---|
| 100 per cent U. S. Extras or better, † weight 24 ounces net per dozen, minimum rate 22 ounces for individual eggs. | 100 per cent U. S. Standards or better, weight 24 ounces net per dozen, minimum rate 22 ounces for individual eggs. | 100 per cent U. S. Trades, U. S. Standard Dirties and U.S. Trade Dirties or better, weight 22 ounces net per dozen, minimum rate 18 ounces for individual eggs. | 100 per cent U. S. Checks or better, no specified or minimum weight required. |

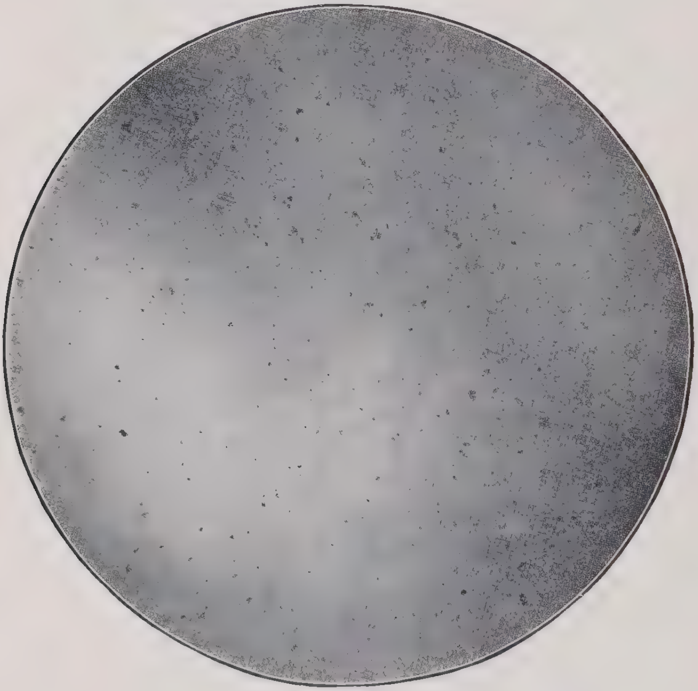
* When conditions warrant, U. S. Checks may be included in the buying grade of U. S. Trades.
† When conditions warrant, a grade of U. S. Specials may be used in buying eggs of a better quality than U. S. Extras.

## VISCOSITY OF ICE CREAM MIX [34]

The viscosity of an ice cream mix is important, in that a liquid without viscosity does not possess the power to retain air when whipped. In other words, an emulsion of oil in air is very unstable. Skim milk has a very small amount of viscosity, because it is fat-free and the casein and other colloids are in a high state of dispersion; therefore, the air that may be beaten in is difficult to retain.

[34] From unpublished data by G. D. Turnbow and F. W. Milner, Agr. Exp. Sta., University of California.

An important colloidal property of cream is its ability to form a stable emulsion with air upon whipping. Cream itself in its aqueous phase is an oil-in-water type of emulsion. In the whipping of cream, the oil-in-water emulsion is changed to an oil-in-air emulsion. The stability of this type of emulsion depends largely upon the size of the air cells. Small air cells, being stronger than large ones, will prevent the structure from collapsing. Also, the greater the number of small



*Courtesy M. Mortensen, Iowa State College*

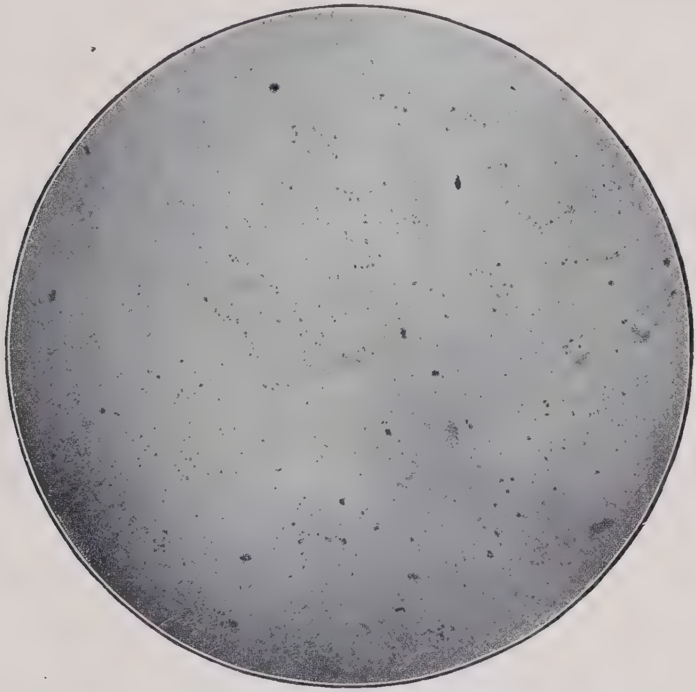
Fig. 36.—Ice Cream Mix. Viscosity 12.25°.

cells, the greater the amount of serum that will be fixed, on account of the greater concentration of the serum at the interfaces.

The size of the air cell is influenced largely by the viscosity and the specific gravity of the mix. Too much viscosity resists the incorporation of air. Air, once incorporated into the mix, will be retained because of the minute size of the air cell. Fresh cream will not whip or develop an oil-in-air emulsion, because it does not possess the property which is developed by allowing the cream to age at low temperatures. The incorporation of air in whipping cream is analogous to the incorporation of air in the ice cream mix.

**Factors Affecting Viscosity.**—There are a number of factors which affect the development of viscosity: namely, (1) ingredients, (2) processing, (3) time and temperature of aging.

There are two types of viscosity in an ice cream mix. One may be defined as *real* viscosity; this is found in all solutions of both crystalloids and colloids, and has no connection with colloidal behavior. The other may be called *apparent* viscosity, and is due to the swelling of sub-



*Courtesy M. Mortensen, Iowa State College*

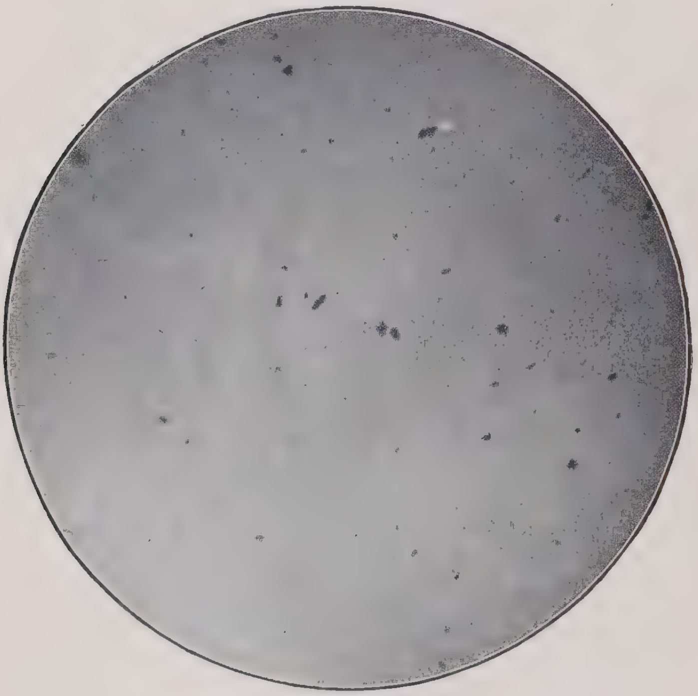
FIG. 37.—Ice Cream Mix. Viscosity 19.50°.

microscopic solid particles in a solution. Apparent or colloïdal viscosity is far more complex than real viscosity.

All the ingredients exert their influence upon the development of viscosity, but in varying amounts. Of those commonly used, the gelatin and other colloids have the greatest effect upon viscosity as they have the physical property of forming a colloidal (network) structure which develops when the mix is aged and held at low temperatures for a period of time. Gelatin has been used in the manufacture of ice cream for years. Though other colloids have been used, the preference for gelatin has gradually increased until now probably 90 per cent of the stabilizing

colloid added is gelatin. Colleges, experiment stations, manufacturers, and others, realizing the necessity of a stabilizing colloid, are giving this protein careful consideration, even though it usually represents only 0.5 of 1 per cent, or less, of the mix.

**Gelatin.**—Gelatin is a protein and may be defined as the most typical of reversible colloids. Owing to its chemical and physical properties, it is an excellent stabilizer of emulsions.



*Courtesy M. Mortensen, Iowa State College*

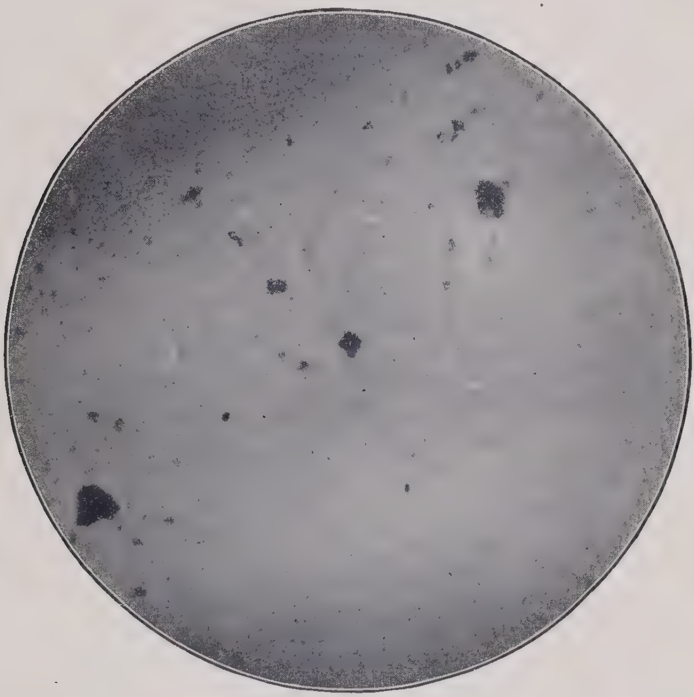
Fig. 38.—Ice Cream Mix. Viscosity 34.50°.

The English word "gelatin" is derived from the Latin word—"*gelatus*,"—meaning congealed, frozen, or stiff. The commercial manufacture of gelatin probably began in the time of William III of Holland, about 1690; ten years later it became a commercial industry in England. Gelatin was valued during these years for its adhesive properties. Not until 1845 was the manufacture of edible gelatin thought of. This was first used for soups, jellies, etc.

The commercial sources of gelatin are animal tissues (skin, connective tissue, cartilage, bones, fish skins, scales, etc.). It is associated with other proteins which are extracted along with gelatin. Some of the more

common of these are collagen, keratin, elastin, mucins, mucoids, chandrigin, humins, and amyloid.

Edible gelatin as usually received by the ice cream manufacturer may be described as being a nearly colorless, odorless, semi-transparent, amorphous substance, containing 10–15 per cent moisture. It has the property of absorbing water and will swell to many times its own volume in cold water. Upon heating it goes readily into colloidal solution.



*Courtesy M. Mortensen, Iowa State College*

Fig. 39.—Cream. Viscosity 69.25°. The Viscosity of Cream is Increased in a Similar Manner to Ice Cream Mix, Due to the Clustering of Fat Globules.

When gelatin is added to a given volume of water, however, the volume decreases rather than increases.[35] It was shown by Wiedemann and Ludeking[36] that this phenomenon was also connected with the liberation of heat. Ice cream containing gelatin is less liable to water crystallization, upon standing, than that containing none.

[35] Quincke, H., Archiv. für die gesamte Physiologie des Menschen und der Tiere, 3 (1870) 322–333.

[36] Wiedemann, E., and Ludeking, Ch., Ann. Physik. Chem., 25 (1885) 145–153.

**Preparing and Adding Gelatin to the Mix.**—Much has been written regarding the proper method of preparing gelatin. Gelatin is usually added to the mix in liquid form, during pasteurization and before homogenization. Work done by the authors and others leads to the opinion that more uniform results, lower bacteria counts, and possibly greater service from the gelatin can be secured by this method. The gelatin is placed in water equal in amount to 3 per cent of the mix, heated to 165° F. in a steam-jacketed kettle, and added to the mix during pasteurization. Heating to a temperature of 175° F.[37] in cases of gelatin of high quality, in no way affected its jelling strength. Only the best gelatin should be considered.

In addition to the method suggested above, gelatin is sometimes added in its dry form to the cold mix before heating to pasteurization temperature. Downey[38] did some preliminary work indicating that the method of preparing and adding the gelatin had little to do with the results obtained. His data do not indicate that the viscosity of the mix was determined in each case. The variation in destruction of viscosity in the freezer and the slight differences in yield are factors hard to control, so that slightly different results may not be conclusive proof. Furthermore, the results of experimental work are valueless unless they are workable when applied in a commercial plant. Commercial procedure should be as simple as possible, and at the same time should allow the process to be carried on uniformly from day to day. The addition of gelatin after homogenization leaves great possibilities for poor ice cream. A cold solution may result in lumpiness and lack of uniform distribution. Homogenizing the gelatin with the pasteurized mix undoubtedly has the effect of concentrating the gelatin as well as the milk proteins in protective films around the fat globules.

The difference in the magnitude of casein and gelatin is due to the fact that the latter possesses a more effective mechanism for increasing its relative volume in solution. The submicroscopic particles of gelatin, or micellæ, occlude large amounts of water, whereby the relative volume occupied by the gelatin is increased. These microscopic particles are the beginning of a continuous gel, to which the gelatin solution has a tendency to set.

There undoubtedly is a colloidal structure built up in an ice cream mix, which has varying degrees of stability. This fact is substantiated by Bogue.[39]

[37] Turnbow, G. D., Before California and Southwestern States Ice Cream Mfrs. Association, Oakland, 1922.

[38] Downey, T. B., Ice Cream Trade Jour., Nov., 1925, p. 81.

[39] Bogue, R. H., Physical and Chemical Properties of Gelatin; Chemistry and Technology of Gelatin and Glue, pp. 146–147. 1922. McGraw-Hill Book Co., Inc.

The viscosity of a crystalloid solution is dependent only upon concentration and temperature, while in the case of colloidal viscosity, quality, concentration, temperature, time, and agitation are all factors of importance. In the case of an ice cream mix, the quality of the gelatin used largely determines the concentration.

Bogue states that the gel consistency is proportional to the undergrade protein present in the gelatin. Loeb[40] and Bogue [41] assume that a gelatin solution contains submicroscopic particles of solid jelly which they call micellæ. These occlude large amounts of water, whereby the relative volume occupied by the gelatin in solution is increased, this condition being the forerunner of the continuous jelly to which the gelatin sets when aged at low temperatures. McBain[42] states that the continuous jelly consists of thread-like aggregates, which increase in number and length as the temperature is lowered, and that at the setting point, where freedom of motion is lost, the adjacent aggregates cohere. The rigidity depends upon the amount of interfacial free solvent and the amount of water hydrated and occluded.

**Hydrogen-ion Concentration of Gelatin.**—The *p*H values of gelatin may be determined by the colorimeteric method as described by Clark,[43] standard buffered solutions being used as a means of comparison. ("The Meaning of Hydrogen Concentration," by W. A. Taylor, La Motte Standards.) It was found that within fairly close limits the *p*H of the gelatin could be made by adding the indicator directly to the dry gelatin and comparing with the standards. This method is not as accurate as the solution method. Other methods for determining gel strength and viscosity are in use, all of which have merit as guides for selecting gelatin. The Burke, Russ, and Lepowitz testers are of the plunger or penetrator type. The finger test, as described by Fernback,[44] is probably the oldest commercial test and, if carefully done, gives a very good idea of the gel strength, provided that the solutions are of the most desirable strength. Many modifications of Fernback's method have been made, but none is of sufficient value to justify detailed description.

**Adjustment of the *p*H of Gelatin.**—Before making jelly strength comparisons, it is necessary to adjust all gelatins to the same *p*H, 6.3 usually being taken as it is approximately that of an ice cream mix.

[40] Loeb, J., Theory of Colloidal behavior, Chapter XI, 1922.

[41] Bogue, R. H., Physical and Chemical Properties of Gelatin; Chemistry and Technology of Gelatin and Glue, p. 147. 1922. McGraw-Hill Book Co., Inc.

[42] McBain, J. W., and Taylor, Ber., 43 (1910), 321; Z. Physik. Chem. 76 (1912), 179; McBain, J. W., and C. S. Salmon, J. Am. Chem. Soc., 42 (1920), 426.

[43] Clark, Determination of Hydrogen Ions, pp. 43–59. Williams and Wilkins Co., Baltimore, Md., 1923.

[44] Fernback, R. I., Glue and Gelatin, p. 47. New York, 1907.

One gram of gelatin is weighed on a balance, then dissolved in 10 c.c. of cold water for fifteen minutes and heated in a water bath at a temperature of 165° F. for fifteen minutes or until fully dissolved. Indicator Brom-Thymol-Blue is added, then acid or alkali until the color exactly matches that of the color standard of *p*H 6.3. The amount of acid or alkali added is noted in each case, and the same quantity is used in making the jelly test. The number of cubic centimeters of acid or alkali is subtracted from the 100 c.c. of water. (For complete tests of gelatin, see page 304.)

**Determination of the *p*H of an Ice Cream Mix.**—The hydrogen-ion concentration of the ice cream mix is determined by a type-K Leeds-Northrop Potentiometer, a Clark Cell, and 0.1 N potassium chloride in the connecting vessel. Hydrogen is generated by hydrolysis. The same amount of mix is used in each determination. The resistance reading is converted to *p*H values by calculation, Clark's formula being used. All samples are placed in a water bath at 20° F. before the determinations are made.

**Complexity of the Mix.**—In the manufacture of ice cream to-day there are three factors which largely cover processing and freezing; namely, (1) ingredients, (2) processing, and (3) freezing.

In any study of milk and its products, one is necessarily dealing with substances that are very complex in their physical and chemical behavior. Milk in itself is, according to Palmer,[45] not only a complex colloidal system but a natural biological emulsion. Generally speaking, it consists of a microscopic dispersion of butterfat in an aqueous plasma containing sugar, ash, and colloidally dispersed proteins such as casein and albumin, all of which have significance when one is dealing with milk itself or products derived therefrom. The chemical and physical changes that may take place are of vital concern. The greater amount of work so far has been confined to the chemical properties of the mix; very little attention has been given to the physical properties.

An ice cream mix represents an emulsion of fat in water, similar in many respects to milk itself, the butterfat being held in the form of a globule by surface tension. The mix presents heterogeneous and homogeneous conditions, being made up of crystalloids, colloids, and suspensions. Quite a wide variation is found in the chemical composition of the components which make up these complex constituents. The rapidity with which the known chemical changes take place remains a question. It is easy, therefore, to understand why investigators have found it hard to interpret them. Chemically speaking, there are really

[45] Palmer, L. S., Chemistry of milk and dairy products from a colloidal standpoint. World's Dairy Congress, Vol. 2, p. 1157.

three types of changes[46]: those taking place instantaneously; those taking place quite rapidly; and those progressing very slowly. The chemical changes themselves are difficult to interpret. The exact effect of the alterations, both chemical and physical, on the ever-changing composition of the ingredients is still in question. Moreover, the chemical composition of the ingredients may be under the control of the human element to only a limited extent. A variation in the composition of such constituents as butterfat and casein will result in other complex chemical and physical changes when these ingredients are thrown into contact with the others present in the ice cream mix.

**Development of Viscosity.**—Probably the most important physical change taking place is the development of viscosity. It has long been known that when milk or cream is allowed to stand, changes take place which alter not only the chemical behavior but the physical properties as well. Investigators have been very much interested in these changes and have given the subject a great deal of consideration. Milk and cream allowed to stand for a period of time at low temperatures become less fluid, in other words, more viscous or sticky. This physical change is due to the development of viscosity.

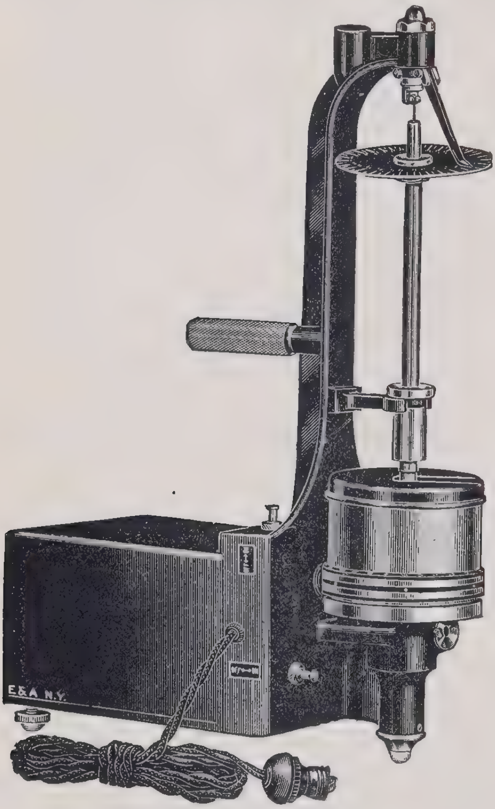
Viscosity is generally defined as the resistance offered by a liquid to shearing, stirring, or flow through a capillary tube. Loeb concludes that in a solution there may be two kinds of viscosity: (1) crystalloidal viscosity, which is found in all solutions of crystalloids or colloids and has no connection with colloidal behavior; (2) colloidal viscosity, which is due to the swelling of submicroscopic particles in the solution. The first is ordinarily termed *real* or *absolute* viscosity, and the second *apparent* viscosity. These may be further differentiated into stable and unstable viscosity. The colloidal viscosity has a greater order of magnitude, in that colloids seem to possess a mechanism which enables them to occupy a greater volume, by the hydration or occlusion of water.

The factors that govern colloidal viscosity are concentration, temperature, and time, while crystalloidal viscosity is affected only by concentration and temperature.

**Determination of Viscosity.**—Viscosity determinations represent the measurement of a force, expressed in dynes, great enough to overcome the resistance of the liquid to flow. Various methods have been devised for making these determinations, each having its advantages and disadvantages. The latest device employed is "The New Improved MacMichael Viscosimeter," which permits rapid determinations and direct reading and insures comparable results with different operators.

[46] Manhart, Gelatin-viscosity and melting resistance. Creamery and Milk Plant Monthly, Sept., 1923, pp. 85–86.

This instrument measures the viscosity of a liquid by measuring the torsion exerted between two cylinders. One of these cylinders is given a rotary motion about its common axis by a motor, which helps in maintaining a constant pressure. The other cylinder is suspended by a fine wire of known torsional strength, which passes through a stem bearing the reading dial, the whole acting on the principle of a pendulum.




*Courtesy of Eimer & Amend*

FIG. 40.—MacMichael Viscosimeter.

The outer cylinder is made to rotate at a uniform and constant speed by means of a small motor, the velocity of which is further regulated by gears and a governor. The electric current can be regulated by means of a rheostat.

The working principle of the "MacMichael" is as follows: the outer cup revolves, the liquid is given a circular motion, which in turn exerts a force on the suspended bob or inner cylinder, causing it to rotate until the torsion of the bob balances the resistance of the liquid and remains in a fixed position, when the reading may be made directly in terms of M's. The reading taken on the dial may be calculated in terms of poises or centipoises by the formula $CP/M = 34.69 \times gm. - cm./M$. The value of gm. – cm./M is furnished by the U. S. Bureau of Standards.

In the case of heavy solutions and of those that are colloidal in structure, the operation of the turntable at a high velocity makes it possible for the movement to be a spiral one instead of a circular flow. The spirals cause eddy currents, giving an inflated reading of deflections. In examining a true solution in which no structure has developed, it is not important for the speed to be so exact that the deflections are pro-

portional to the speed, because agitation does not destroy viscosity in this case.

In the Doolittle instrument, another device for measuring viscosity by means of torsion, the readings are made by the retardation effect that the liquid exerts upon a suspended ball of specific size.

There are on the market a number of capillary viscosimeters which are used in determining the viscosity of an ice cream mix. The principal disadvantages of this type of instrument are as follows: (1) the time of flow is not strictly proportional to the viscosity, but varies inversely with the density; (2) the flow at the end is in the form of drops rather than in a stream; (3) temperature control is difficult; (4) pressure does not remain constant.

It is certain that a colloidal structure exists in an ice cream mix, because of the fact that the structure may be mechanically broken. A sample shows a diminution in viscosity when passed through an ordinary capillary viscosimeter for a second time. This is also true in the case of a torsional machine. Agitation during freezing has a tendency to destroy viscosity. This phase of viscosity is discussed later.

**Effect of Gelatin on Viscosity.**—That a good grade of gelatin exerts the greatest influence of any ingredient upon the viscosity of the mix, when aged, was demonstrated by work done at the University of California Agricultural Experiment Station. A mix containing 10.8 per cent fat and 36 per cent total solids was processed according to standard technique, except that the gelatin was withheld from the mix when passed through the homogenizer and over the cooler. Samples containing no gelatin were taken. Five-tenths per cent gelatin was added and samples taken.

TABLE XXIV *

EFFECT OF GELATIN (0.5 PER CENT) UPON VISCOSITY

| Time, Hours | Before Gelatin Added, Poises | After Gelatin Added, Poises |
|---|---|---|
| 0 | .649 | 2.37 |
| 24 | ................ | 9.84 |
| 48 | ................ | 10.51 |
| 72 | ................ | 9.03 |
| 96 | ................ | 11.99 |
| 120 | ................ | 12.03 |

* Typical example of data.

A comparison of the results shows that the addition of gelatin to the mix causes a tremendous increase in the viscosity. There was quite a rapid increase during the first twenty-four hours, and a slight one during the second twenty-four. The third twenty-four hours showed a slight decrease. The conclusion, therefore, is that twenty-four hours is sufficient to age a mix. Table XXIV shows beyond any doubt that gelatin has a tremendous influence on the viscosity of the ice cream mix by the development of a distinctive colloidal structure. The quality and the amount of gelatin present influences this greatly. This fact was demonstrated when a mix containing 10.78 per cent fat and 36.79 per cent total solids was processed as usual except that the mix was passed over the cooler and varying amounts of gelatin were added.

TABLE XXV *

EFFECT OF VARYING AMOUNTS OF GELATIN †

| Time, Hours | Amount of Gelatin, Per Cent | Viscosity, Poises |
|---|---|---|
| 24 | 0.2 | 0.646 |
| 24 | 0 3 | 1.020 |
| 24 | 0.4 | 4.280 |
| 24 | 0.5 | 12.280 |
| 24 | 0.6 | 28.920 |
| 48 | 0.3 | 1.42 |
| 48 | 0.4 | 5.64 |
| 48 | 0.5 | 18.60 |
| 48 | 0.6 | Too heavy to run |

* Typical example of data.
† Similar results were obtained by Moore, Combs and Dahle, Jour. Da. Sci., V. 8, p. 500–14, No. 6, 1925.

The data in the foregoing table show clearly that an increase in the amount of gelatin is accompanied by an increase is viscosity, but not by an increase proportionate to the concentration. At concentrations of 0.4 and 0.5 per cent, the increase in viscosity is very great after the first twenty-four hours, but for the next twenty-four hours it is not so rapid. The rate of increase in viscosity in the concentration of 0.3 per cent and lower is much less. Hatschek[47] states that a certain minimum concentration is necessary to form a jelly at a given temperature. Variations

[47] Hatschek, E., Physics and Chemistry of Colloids, p. 82. P. Blakiston's Son & Co., 1922.

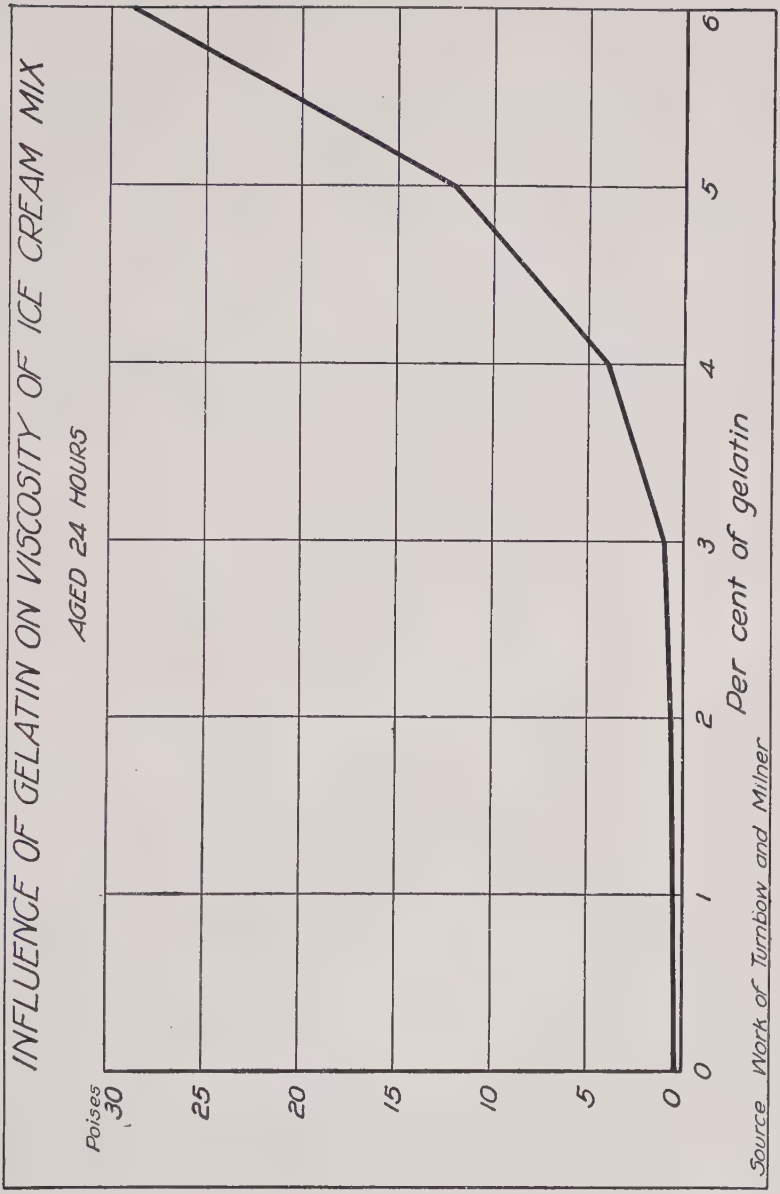

INFLUENCE OF GELATIN ON VISCOSITY OF ICE CREAM MIX
AGED 24 HOURS
Poises
30
25
20
15
10
5
0
0
1
2
3
4
5
6
Per cent of gelatin
Source Work of Turnbow and Milner

FIG. 41.

occur with brands and grades; a concentration of less than .25 per cent will not set even at 0° C. As the concentration increases, the melting and setting points rise. Gelatins of low concentration set steadily during the first few days, soon reaching a maximum.

**Effect of Quality of Gelatin on Viscosity.**—It is known that the quality of the gelatin exerts a great influence upon the amount of viscosity that will develop in an ice cream mix. The better the quality of gelatin, the greater the jelling power; and the greater gel strength, the greater the viscosity developed.

To demonstrate the above statement, a mix was made containing an average of 11.01 per cent butterfat and 36.84 per cent total solids. This was processed as usual except that samples were taken from the cooler and to them was added the same amount of the different grades of gelatin. The results show quite a wide variation in the viscosity of the respective mixes.

TABLE XXVI

Effect of Grade of Gelatin on Viscosity

| Sample | Grade of Gelatin | Viscosity | |
|---|---|---|---|
| | | 24 hours, poises | 48 hours, poises |
| 1 | Poor | 2.60 | 9.36 |
| 4 | Fair | 9.36 | 15.08 |
| 2 | Good | 13.52 | 26.00 |
| 5 | Excellent | 28.62 | Solid jelly |

The better the grade of gelatin, the greater the viscosity. Manhart[48] found that ice cream from a mix made with 0.6 per cent of a poor grade of gelatin was about equal in viscosity and melting resistance to one made with 0.4 per cent of good gelatin. These results parallel quite closely Downey's[49] work.

Some authorities state that a good gelatin should make up a clear solution. The authors' study of gelatin does not indicate that color bears any great definite relation to gel strength, solubility, rate of setting, or odor.

[48] Manhart, V. C., Gelatin-viscosity and melting resistance. Creamery and Milk Plant Monthly, Sept., 1923, p. 85.

[49] Downey, Ice Cream Trade Journal, Nov., 1925, p. 81.

The gelatins on the market vary in $p$H values. Some make up clear solutions in water. When their $p$H is changed they may become turbid upon approaching the iso-electric point. A turbid gelatin can be made clear by a change in acidity that is away from the iso-electric point. However, when the $p$H is altered away from the iso-electric point, the gel strength and viscosity are weakened. Bogue,[50] in accounting for these changes, states that "the greatest opacity results from the largest aggregates of less swollen particles. This maximum of opacity occurs at the iso-electric point. Any decrease in the size of the aggregates or increase in the hydration results in greater clarity or transparency of the solution."

This means that almost any gelatin may be made clear or turbid by altering its $p$H away from or toward its iso-electric point.

The following table typically illustrates the effect of the $p$H on clarity of the gelatin solution.

TABLE XXVII

EFFECT OF $p$H UPON COLOR

| Sample | $p$H | Color |
|---|---|---|
| 1 | 7.0 | Clear |
| 1 | 4.7 | Turbid |
| 1 | 3.0 | Clear |
| 4 | 5.3 | Turbid (slightly) |
| 4 | 4.7 | Turbid |
| 4 | 3.0 | Clear |
| 2 | 6.6 | Clear |
| 2 | 4.7 | Turbid |
| 2 | 3.0 | Clear |

The gel strength is influenced markedly by the $p$H of the gelatin, as is shown by the inversion test. A weak gelatin may be strengthened if it has, for illustration, a $p$H of 7.0 or 3.0, by changing to approximately 4.7. This does not mean that it would be possible to take a poor grade of gelatin and, by changing the $p$H, make a high-grade gelatin, although the grade may be improved somewhat. The odor of gelatin in water solution, warmed to approximately 140–160°, indicates the grade to some extent.

[50] Bogue, R. H., Chemistry and Technology of Gelatin and Glue, p. 156. McGraw-Hill Book Co., 1922.

Liquefying and putrefactive organisms do not grow in a medium that has a high $p$H. Therefore, gelatin that is apparently uncontaminated may show the presence of large numbers of these organisms when the $p$H is lowered. Some gelatins are sold to the trade with a $p$H so high (high acid) that these undesirable types will not develop upon incubation in a water solution.

Since the strongest gel is obtained when the gelatin is at a $p$H of approximately 4.7, and an ice cream mix under factory conditions is approximately 6.3 (this figure varies slightly, depending upon sources and quality of products used), the question arises whether the large reservoir of salts in the mix is sufficient to change the $p$H of the gelatin without materially changing the $p$H of the ice cream mix. If this is so, then gelatin should be purchased upon a little different basis from that used in the past.

As would be expected, the usual range in the $p$H value of gelatin affects but little the $p$H of an ice cream mix. The effect, if any, is of no commercial importance.

TABLE XXVIII

EFFECT OF $p$H OF GELATIN UPON $p$H OF MIX

| Mix Number | Sample | $p$H of Gelatin | $p$H of Mix |
|---|---|---|---|
| A | 1 | 7.6 | 6.27 |
| A | 2 | 3.8 | 6.23 |
| A | 3 | 3.8 | 6.17 |
| A | 4 | 4.0 | 6.18 |
| A | 5 | No Gelatin | 6.24 |
| B | 6 | 4.7 | 6.42 |
| B | 7 | 3.0 | 6.21 |
| B | 8 | 6.3 | 6.25 |
| B | 9 | 8.0 | 6.30 |
| B | 10 | No Gelatin | 6.31 |
| C | 11 | 4.2 | 6.33 |
| C | 12 | 7.0 | 6.37 |
| C | 13 | 3.8 | 6.23 |
| C | 14 | 5.8 | 6.26 |
| C | 15 | No Gelatin | 6.30 |
| D | 16 | 3.8 | 6.27 |
| D | 17 | 7.0 | 6.33 |
| D | 18 | 4.0 | 6.26 |
| D | 19 | 7.6 | 6.28 |
| D | 20 | No Gelatin | 6.29 |

From the data above, it is safe to conclude that the gelatin, regardless of its $p$H, changes to that of the ice cream mix. Undoubtedly, there are present in the average ice cream mix sufficient salts to change the $p$H of the gelatin to that of the mix. As shown by the table above, each mix was divided into five parts, to four of which 0.5 of 1 per cent of gelatin of varying $p$H values was added, while to the fifth no gelatin was added. All of the readings quoted above represent four or more $p$H determinations. The variations in a mix with different gelatins, while excessive in some types of solutions, are not considered so in ice cream, because of its complexity.

**Effect of Butterfat and Serum Solids upon Viscosity.**—Dahlberg[51] in his recent work showed that butterfat had a decided influence upon the viscosity of cream, but that a greater effect was noticeable when the fat content was 20 per cent or more. The milk solids-not-fat did not alter materially the viscosity of the cream.

A mix was made up with all ingredients to contain 11.43 per cent butterfat and 37.5 per cent total solids, and was processed in the usual manner except that all of the ingredients that supplied the butterfat were withheld, as was also the gelatin. The ingredient supplying the butterfat was added in four quantities. After each addition, a sample was taken and the mix poured back into the hotwell, to which additional fat was added. After the last addition of fat, a sample of the mix was taken and the gelatin then added. All sampling was done at the cooler after homogenization and cooling.

TABLE XXIX

EFFECT OF BUTTERFAT, SERUM SOLIDS, AND GELATIN ON VISCOSITY

| Sample | Per Cent Fat | Per Cent Gelatin | Per Cent S. S. | Viscosity, Poises |
|---|---|---|---|---|
| 1 | 0 | None | 14.3 | 1.36 |
| 2 | 3.1 | None | 12.3 | 0.81 |
| 3 | 7.6 | None | 11.5 | 1.36 |
| 4 | 10.8 | None | 10.8 | 2.72 |
| 5 | 11.4 | 0.5 | 10.4 | 25.50 |

From the data, it seems that butterfat exerts an influence upon the viscosity of the mix. The effect of the butterfat below 7 per cent was not noticeable. With the addition of the gelatin, there was a marked increase in viscosity. That of the sample without butterfat is due to the

[51] Dahlberg, A. C. Tech. Bul. 113, Geneva, N. Y.

concentration of milk solids-not-fat and to the sugar. According to Clayton,[52] when no butterfat is present in milk or cream, the casein and other constituents are in a high state of dispersion, and in the absence of the butterfat the colloids cannot be adsorbed. During the aging of the ice cream mix, it is assumed that the increases in viscosity are due to the adsorption of the casein and other hydrophile colloids by the fat. With an increase in the amount of fat, or with the division of the fat globules by homogenization, there is a corresponding increase in the surface area to which colloids may be adsorbed, the fat being in the form of globules the size of which influences the amount of colloids adsorbed. Dahlberg[53] found that the viscosity was altered by the addition of the butterfat, which affected the grouping of the globules.

**Gums, Tragacanth and Arabic.**—Gums in ice cream must be considered fillers and not stabilizers. It is the belief of the authors that these products have no place in the manufacture of ice cream. They perform no function, as does gelatin, and are comparable to it only as fillers.

Gum tragacanth may have a place in combination with some other colloid, such as agar. The authors have manufactured some very desirable ice cream using a combination of these two colloids.

**Effect of Processing upon Viscosity.**—A jelly can exist only when the relative volume occupied by the swollen molecular threads has become so great that all motion is lost. As the temperature falls, the threads lengthen and hydration increases.

In further work on viscosity, a mix which contained 10.82 per cent fat and 35.7 per cent total solids was made as usual. From the samples taken at the cooler, viscosity determinations were made for each twenty-four of one hundred and forty-four hours.

From the following data, it is found that the viscosity of the mix increased for each twenty-four hours, except for the characteristic drop at the end of the second twenty-four hours. The increase after the first seventy-two hours was very small. At the end of ninety-six hours, a slight decrease was noted, and then an increase occurred. These changes in viscosity seem to be characteristic of some gelatins. Observations made on other mixes, treated similarly, showed that in some cases the viscosity dropped somewhat at the end of the first forty-eight hours, then increased again slightly. Hatschek[54] states that a gelatin

[52] Clayton, Gelatin, Fifth Report Colloid Chemistry, London, p. 42.

[53] Dahlberg, Viscosity, surface tension and whipping qualities of milk and cream. Tech. Bul. 113, Geneva, N. Y.

[54] Hatschek, E., Physics and Chemistry of Colloids, p. 116. P. Blakiston's Son & Co., 1922.

TABLE XXX

EFFECT OF HOMOGENIZATION ON VISCOSITY

| Time, Hours | Before Homogenization, Poises | After Homogenization, Poises |
|---|---|---|
| 0 | .561 | .66 |
| 24 | .............. | 3.07 |
| 48 | .............. | 1.40 |
| 72 | .............. | 7.95 |
| 96 | .............. | 7.57 |
| 120 | .............. | 8.36 |
| 144 | .............. | 9.01 |

solution does not attain its full strength immediately upon setting, but that the modulus increases for some time.

Aging does not affect the freezing point, if the process goes on at a temperature low enough to prevent the development of acid. The following table[55] demonstrates this very clearly.

TABLE XXXI

EFFECT OF AGE UPON FREEZING POINT

| Freezing Point, ° F. | Time (Age) | Per Cent Total Solids | Per Cent Serum Solids | Per Cent Fat |
|---|---|---|---|---|
| 28.4 | None | 33.4 | 12.2 | 8.3 |
| 28.4 | 3 days | 33.4 | 12.2 | 8.3 |
| 28.4 | 1 week | 33.4 | 12.2 | 8.3 |
| 28.4 | 2 weeks | 33.4 | 12.2 | 8.3 |
| 28.4 | 4 weeks | 33.4 | 12.2 | 8.3 |

**Effect of Sugar upon Viscosity.**—Sugar is a carbohydrate with a complex structure. When added to water or milk it tends to go into molecular dispersion with the formation of a homogeneous mixture.

A mix was made to contain 11.12 per cent butterfat and 36.8 per cent total solids; it was processed as usual, except that the sugar and the gelatin were withheld. A sample, which did not contain sugar or gelatin,

[55] Parfitt and Taylor, Effects of ingredients in the ice cream mix on its freezing point. Journal of Dairy Science, May, 1925, Vol. 8, pp. 230–237.

was taken. The gelatin and the sugar were added, after which another sample was taken. The results show that the sugar exerted a very limited influence upon the viscosity.

TABLE XXXII.*

EFFECT OF SUGAR UPON VISCOSITY

| Treatment | Time, Hours | Viscosity, Poises |
|---|---|---|
| No sugar or gelatin...... | 48 | 0.136 |
| Sugar, no gelatin......... | 48 | 0.455 |
| Complete mix........... | 48 | 12.240 |

* Typical example of data.

A slight increase in the viscosity was noted as soon as the sugar was added. Upon the addition of a small amount of gelatin, a tremendous increase in the viscosity took place. With the addition of sugar at the same concentration as that of the ice cream mix, the viscosity of the solution became 300 per cent greater than that of water. As the concentration of the sugar increased, the viscosity likewise increased. When crystalloids go into solution, the viscosity of the solution is slightly greater than that of the pure solvent, and the viscosity increases with the concentration. The rate of increase will be greater in concentrated solutions than in dilute ones.

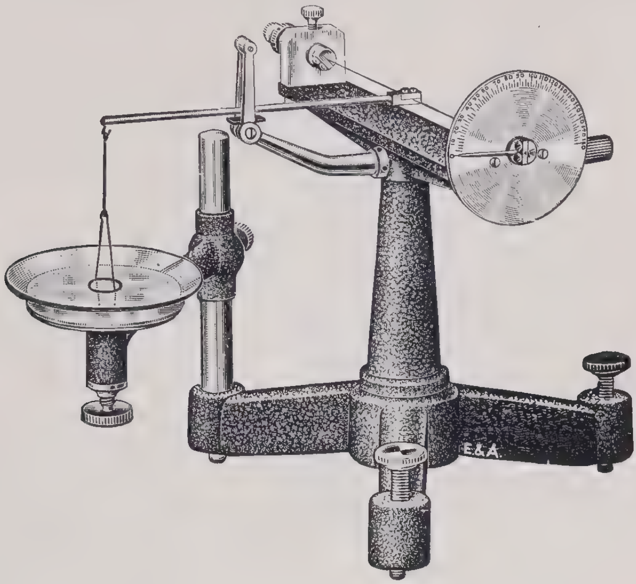
**Surface Tension.**—The ice cream mix is known to possess surface tension, as do all liquids, but the importance of its surface tension has not been definitely determined.

If a clean glass tube is inserted into the mix, the latter appears to climb up the tube. This is true of all liquids that wet a tube. Since mercury does not wet a tube, it would behave in the opposite manner. The film on top of a liquid varies in strength for different liquids, and the measurement of its strength is known as the measurement of surface tension. Bogue[56] says that nearly all inorganic salts in solution increase the surface tension of the solvent, while colloids of the suspensoid class, as a rule, do not affect surface tension. Practically all emulsoid colloids lower the surface tension, gelatin not as much as some others, however. Surface tension decreases as the temperature rises.

The surface tension of an ice cream mix, as determined by the

[56] Bogue, Chemistry and Technology of Gelatin and Glue, p. 114. McGraw-Hill Book Co., 1922.

Du Nouy Surface Tension apparatus, varies with the composition and the salts it contains. Increasing the dispersed phases makes the continuous phase, separating the fat globules, thicker, and raises the surface




*Courtesy Eimer & Amend*

Fig. 42.—du Nouy Surface Tension Apparatus.

tension. In determining the surface tension of an ice cream mix, uniform amounts and careful control of temperature are especially necessary. The determination requires three or four minutes. The lower the surface tension, the faster the mix whips in the freezer.

# CHAPTER VI

## CALCULATION OF THE ICE CREAM MIX

One of the important steps in the manufacture of ice cream of high quality is the proper proportioning of the ingredients. Formulæ are used by a few ice cream manufacturers, but a thorough knowledge of the procedure of standardizing the mix (mixture), by using ingredients of varying composition to bring about the desired percentage of fat, milk solids-not-fat, total solids, etc., is of greater value than the possession of a great number of formulæ.

The ability to calculate a mix simply and accurately is very useful to the ice cream manufacturer. For a long time most mixes were calculated by trial and error. An algebraic method[1] has been devised to replace this slow and clumsy one. Manufacturers who understand this new method, and have their products standardized, do not need to calculate a new mix each time one is desired. First of all the percentage of the various ingredients must be decided upon. Then the legal standard must be considered. If the ice cream is to be sold entirely within the state in which it is manufactured, only the state standard need be considered. If, however, some of the ice cream is intended for interstate shipment, the federal requirements must be met.

The cost of the ingredients is the next factor of importance to consider. The processing costs do not vary materially with changes in the composition of the mix. Sugar is the cheapest solid used, and a highly desirable one up to a certain point. Good ice cream usually contains not less than 14.5 per cent or more than 15.5 per cent sugar. Milk solids-not-fat come next in lowest cost to the pound. The desirability of using the maximum need not be discussed here. Ten to 11 per cent is about the maximum amount of skim-milk solids that may be used ordinarily, since allowance must be made for slight variations in the tests and weights, and a safe margin must be maintained below that point where there is danger of sandy ice cream. Under conditions explained elsewhere, larger amounts or milk solids-not-fat can be used without danger of developing sandy ice cream.

[1] Turnbow, G. D., and Titus, C. M., Vol. 1, No. 4, Hilgardia, University of Calif.

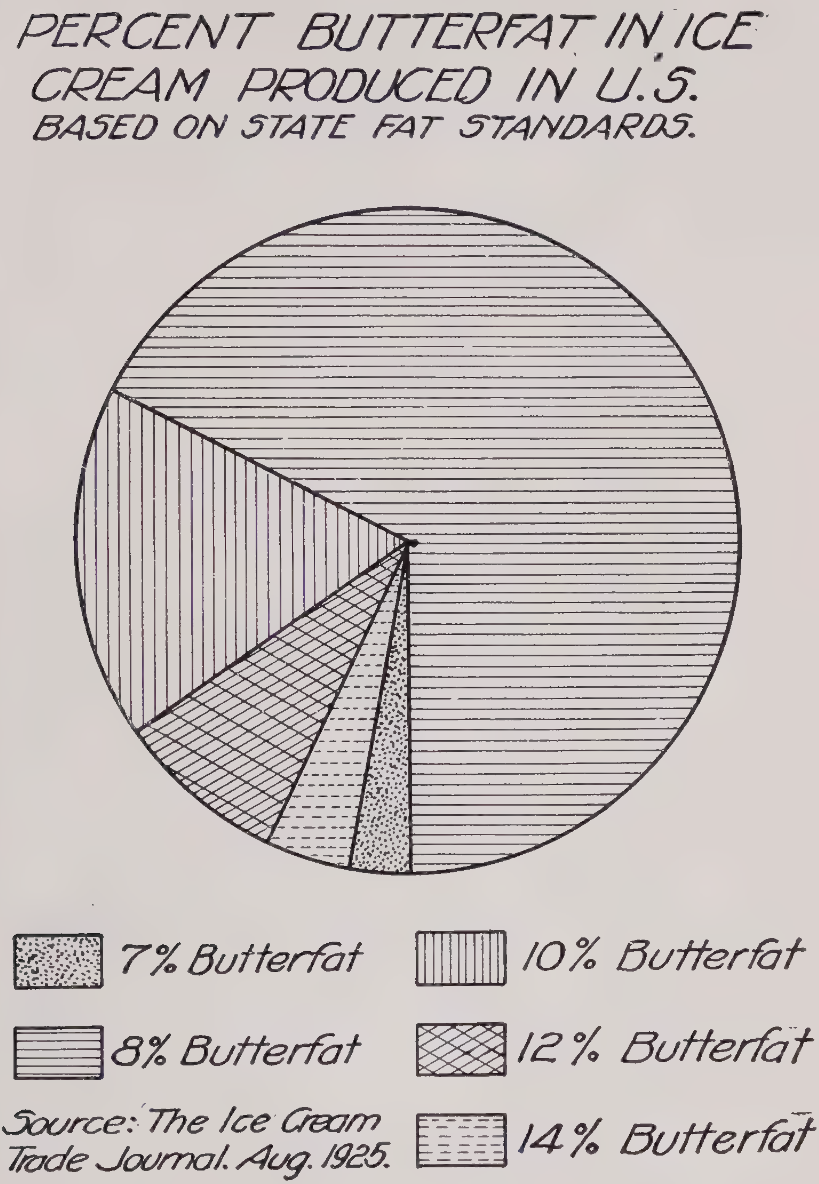

PERCENT BUTTERFAT IN ICE CREAM PRODUCED IN U.S.
BASED ON STATE FAT STANDARDS.
7% Butterfat
10% Butterfat
8% Butterfat
12% Butterfat
14% Butterfat
Source: The Ice Cream Trade Journal. Aug. 1925.

FIG. 43.

Gelatin limits itself because of its action in the mix. The amount to be used varies between 0.3 and 0.5 per cent, depending on the quality of the gelatin, the method of preparation, and the climate.

The last and most expensive ingredient is butterfat. It is essential that the commercial mix contain at least the minimum butterfat required by law. Some manufacturers make a practice of exceeding this limit by a safe margin, and others add considerably more than the requirements. In the latter instance, there are generally market influences of an unusual type to be met.

A good ice cream, therefore, can be manufactured containing:

10.5 per cent fat
10.0 per cent milk solids-not-fat
14.5 per cent sugar
0.5 per cent gelatin
3.0 per cent water for hydrating gelatin.

This mix has a total solids content of 35.5 per cent and, with an overrun of 90 to 95 per cent, will produce a good ice cream.

To suggest a uniform standard for all states at the present, or to find one that will meet the personal favor of all manufacturers of ice cream, is obviously impossible. It would reflect great credit on the industry if it had so perfected its product that a universal standard could be adopted. The following table of state and Federal standards indicates the reason for the present variety of standards:

**Algebraic Method.**—As suggested above, the method here explained involves the use of algebraic formulæ and the rules based on them. There are formulæ covering nearly every possible combination of dairy products. The chief advantage in using them lies in the fact that mathematical accuracy in computing mixes may be insured. With a little knowledge of elementary algebra, the formulæ will be found very simple. Those who have no knowledge whatever of algebra will find it best to use the rules at first. Comparing the rules with the formulæ and studying the examples worked out by means of the latter will result in an understanding and proficiency in the calculation of mixes. Eleven possible combinations of dairy products have been worked out with the formulæ. There may be other combinations, but these are the most important ones.

## TABLE XXXIII *

### Legal Standards of Butterfat and Gelatin in Ice Cream

| State | Plain Ice Cream | | Fruit and Nut Ice Cream | |
|---|---|---|---|---|
| | Fat | Gelatin | Fat | Gelatin |
| | Per Cent | Per Cent | Per Cent | Per Cent |
| Alabama | ... | ... | ... | ... |
| Alaska ** | ... | ... | ... | ... |
| Arizona | ... | ... | ... | ... |
| Arkansas | (1) | (1) | (1) | (1) |
| California | 10 | 0.6 | 8.0 | 0.6 |
| Colorado | 14 | ... | 12.0 | ... |
| Connecticut ** | ... | ... | ... | ... |
| Delaware ** | ... | ... | ... | ... |
| District of Columbia ** | ... | ... | ... | ... |
| Florida | 14 | ... | 12.0 | ... |
| Georgia | 8 | ... | 8.0 | ... |
| Hawaii ** | ... | ... | ... | ... |
| Idaho | 14 | (2) | 12.0 | (2) |
| Illinois | 8 | ... | 8.0 | ... |
| Indiana | 8 | 0.7 | 8.0 | 0.7 |
| Iowa | 12 | 1.0 | 10.0 | 1.0 |
| Kansas | 10 | ... | 10.0 | ... |
| Kentucky | 10 | ... | 8.0 | ... |
| Louisiana | 10 | 1.0 | 8.0 | 1.0 |
| Maine | 14 | ... | 12.0 | ... |
| Maryland | 8 | 1.0 | 6.0 | 1.0 |
| Massachusetts | 7 | ... | 7.0 | ... |
| Michigan | 10 | 0.7 | 8.0 | 0.7 |
| Minnesota | 12 | 1.0 | 10.0 | 1.0 |
| Mississippi | 8 | 0.5 | 8.0 | 0.5 |
| Missouri | 8 | ... | 8.0 | ... |
| Montana | 10 | 1.0 | 9.0 | 1.0 |
| Nebraska | 14 | ... | 12.0 | ... |
| New Hampshire | 14 | 0.2 | 14.0 | 0.2 |
| New Jersey | 8 | ... | 6.0 | ... |
| New Mexico | ... | ... | ... | ... |
| Nevada | 14 | ... | 12.0 | ... |
| New York | 8 | ... | 6.5 | ... |
| North Carolina | 8 | 0.2 | 8.0 | 0.2 |
| North Dakota | 12 | (3, 4) | 10.0 | (3, 4) |
| Ohio | 8 | 0.5 | 8.0 | 0.5 |
| Oklahoma | 10 | ... | 8.0 | ... |
| Oregon ** | 12 | 1.0 | 9.0 | 1.0 |
| Pennsylvania | 8 | 0.5 | 6.0 | 0.5 |
| Philippine Islands | 14 | ... | 12.0 | ... |
| Porto Rico ** | ... | ... | ... | ... |
| Rhode Island | 8 | 1.0 | 8.0 | 1.0 |
| South Carolina | ... | ... | ... | ... |
| South Dakota | 14 | ... | 12.0 | ... |
| Tennessee | 8 | ... | 6.0 | ... |
| Texas | 8 | 0.2 | 6.0 | 0.2 |
| Utah | (1) | (1) | (1) | (1) |
| Vermont | 14 | ... | 12.0 | ... |
| Virginia | 8 | 0.25 | 8.0 | 0.25 |
| Washington | 8 | ... | 8.0 | ... |
| West Virginia | ... | 0.5 | ... | 0.5 |
| Wisconsin | 12 | 0.5 | 10.0 | 0.5 |
| Wyoming | 10 | ... | 10.0 | ... |
| United States | 14 | ... | 12.0 | ... |

(1) Federal standard.
(2) Not allowed.
(3) Two ounces in 10 gallons.
(4) Must be labeled "Gelatin ice cream."

Note. The above standards are correct on date of October 1, 1923, according to the offices in the various States having the enforcement of the laws in charge. In those States or possessions where no reply was received the name of the State or possession is followed by two asterisks (**). The remainder of the report was made up from Melvin, A. D., Legal Standard for Dairy Products, United States Department of Agriculture, 1916. If a space is left blank, no standard exists. North Carolina permits what it terms "compound ice cream" which may contain 4 per cent butterfat and must be labeled "compound ice cream."

* Combs, W. B., Standardizing the ice cream mix. Proc. World's Dairy Congress, 1923, Vol. 1, p. 490.

## POSSIBLE COMBINATIONS

**Case I.**—Cream, milk, condensed skim milk, or cream and condensed skim, or maximum amount of cream.

**Case II.**—Milk, cream, sweetened condensed skim, or cream, milk, plain condensed whole milk, or cream, sweetened condensed, whole milk.

**Case III.**—Milk, cream, and condensation.

**Case IV.**—Cream, skim and condensed skim.

**Case V.**—Left-overs.

**Case VI.**—Using a given amount of sweet butter and cream.

**Case VII.**—Using given amounts of two or more ingredients.

**Case VIII.**—Other standards.

After the amount of milk or cream that is to go into the mix is calculated, the following table is of assistance in determining the amount of milk solids-not-fat contained in that much milk or cream:

TABLE XXXIV *

PERCENTAGE OF FAT AND MILK SOLIDS-NOT-FAT IN MILK AND CREAM

| Product | Per Cent Fat | Per Cent Milk Solids-not-fat † | Product | Per Cent Fat | Per Cent Milk Solids-not-fat † |
|---|---|---|---|---|---|
| Water | 0.00 | 0.00 | Cream | 30.0 | 6.2 |
| Skim milk | .02 ‡ | 8.9 | Cream | 31.0 | 6.2 |
| Milk | 3.0 | 8.6 | Cream | 32.0 | 6.1 |
| Milk | 3.5 | 8.7 | Cream | 33.0 | 6.0 |
| Milk | 4.0 | 8.8 | Cream | 34.0 | 5.9 |
| Milk | 4.5 | 8.9 | Cream | 35.0 | 5.8 |
| Milk | 5.0 | 9.0 | Cream | 36.0 | 5.7 |
| Cream | 15.0 | 7.6 | Cream | 37.0 | 5.6 |
| Cream | 16.0 | 7.5 | Cream | 38.0 | 5.5 |
| Cream | 17.0 | 7.4 | Cream | 39.0 | 5.4 |
| Cream | 18.0 | 7.3 | Cream | 40.0 | 5.4 |
| Cream | 19.0 | 7.2 | Cream | 41.0 | 5.3 |
| Cream | 20.0 | 7.1 | Cream | 42.0 | 5.2 |
| Cream | 21.0 | 7.0 | Cream | 43.0 | 5.1 |
| Cream | 22.0 | 7.0 | Cream | 44.0 | 5.0 |
| Cream | 23.0 | 6.9 | Cream | 45.0 | 4.9 |
| Cream | 24.0 | 6.8 | Cream | 46.0 | 4.8 |
| Cream | 25.0 | 6.7 | Cream | 47.0 | 4.7 |
| Cream | 26.0 | 6.6 | Cream | 48.0 | 4.6 |
| Cream | 27.0 | 6.5 | Cream | 49.0 | 4.5 |
| Cream | 28 0 | 6 4 | Cream | 50.0 | 4.5 |
| Cream | 29.0 | 6.3 | | | |

* Taken in part from Farrington and Woll.

† For all practical purposes, only the nearest tenth per cent of milk solids-not-fat may be used.

‡ This small amount of fat is not given consideration.

**Case I. Milk, Cream, Condensed Skim.**—Several different combinations of ingredients are used in ice cream, the most common one being milk (or skim milk), cream (or butter), and plain condensed skim. This combination is treated first and called Case I.

Let $M$ = No. lbs. of mix;
$a$ = % fat in milk;[2]
$b$ = % fat in cream or butter;
$c$ = % M.S.N.F. (milk solids-not-fat) in condensed skim;[3]
$d$ = % M.S.N.F. in milk or skim milk;
$e$ = % M.S.N.F. in cream.

The sugar, gelatin, and water make up 14.5% + 0.5% + 3.0%, or 18% of the mix.

Hence, 100% − 18% = 82% (or .82) of the mix consists of dairy products; namely, milk, skim milk, or butter and condensed skim.

Now, let $X$ = No. lbs. of "$a$" % milk required;
$Y$ = No. lbs. of "$b$" % cream required;
$Z$ = No. lbs. of "$c$" % condensed skim required.

Then the formulæ are as follows:

$$Z = \frac{10(b - a) + 10.5(d - e) - .82(bd - ae)}{c(b - a) - (bd - ae)} \times M;$$

$$Y = \frac{(10.5 - .82a)M + aZ}{b - a};$$

$$X = \frac{10.5M - bY}{a}.$$

It should be remembered that $bd$ means $b$ times $d$, $be - ae$ means to subtract $a$ times $e$ from $b$ times $d$, etc. $10(b - a)$ means to subtract $a$ from $b$ and multiply the difference by 10, etc.

Next, an example is worked out showing how to substitute in the formulæ, and then a shorter solution of the same example is given. Afterward the corresponding rules are stated, pages 142 to 143.

Example IA (*Milk, Cream, and Condensed Skim*).[4]—Using standard mix with ingredients having the following composition to make 1000 lbs. of mix:

Milk, 4% fat
Cream, 35% fat
Condensed skim, 32% M.S.N.F.

[2] Thus if 4 per cent milk is used, $a = 4$.

[3] Thus if 32 per cent condensed skim is used, $c = 32$.

[4] The examples are numbered according to Cases; e.g., in Case I there are problems IA, IB, IC, etc.

Thus:

$a = 4, \quad b = 35, \quad c = 32$

From table $\quad d=8.8$*

$e=5.8$

Then, substituting these numbers in the formula for $Z$,

$$Z = \frac{10(35-4) + 10.5(8.8-5.8) - .82(35 \times 8.8 - 4 \times 5.8)}{32(35-4) - (35 \times 8.8 - 4 \times 5.8)} \times 1000$$

$$= \frac{10 \times 31 + 10.5 \times 3.0 - .82(308.0 - 23.2)}{32 \times 31 - 284.8} \times 1000$$

$$= \frac{310 + 31.5 - 233.5}{992 - 284.8} \times 1000 = \frac{108.0}{707.2} \times 1000$$

$= 152.7$ lbs. condensed skim

Now, substituting in the formula for $Y$, we have

$$Y = \frac{(10.5 - .82 \times 4) \times 1000 + 4 \times 152.7}{35 - 4}$$

$$= \frac{7220 + 610.8}{31} = \frac{7830.8}{31} = 252.6 \text{ lbs. of cream}$$

To find $X$, we have

$$X = \frac{10.5 \times 1000 - 35 \times 252.6}{4}$$

$$= \frac{10{,}500 - 8{,}841}{4} = 414.8 \text{ lbs. of milk}$$

Preliminary Check:
Total Dairy products = .82 × 1000 lbs. = 820 lbs.

152.7
252.6
414.8

820.1, Check

The complete "check" follows:[5]

10.5% of 1000 lbs. = 105 lbs. of fat required

In this case there are only two sources of fat, namely, milk and cream.

| | | |
|---|---|---|
| 4% of 414.8 lbs. | = | 16.59 lbs. fat from milk. |
| 35% of 252.6 lbs. | = | 88.41 lbs. fat from cream. |
| | | 105.00 lbs. of fat altogether, which "checks" with the fat required. |

[5] It must be noted that the preliminary check given above is not a perfect "check," since the amounts obtained for all the different ingredients might be wrong and yet they might total 820 lbs. Hence, the more complete check should always be used.

The M.S.N.F. = 10% of 1000 lbs. = 100 lbs. required. There are three sources of M.S.N.F. in this case, namely: milk containing 8.8% cream containing 5.8%, and condensed skim containing 32%.

$$\begin{array}{rll}
8.8\% \text{ of } 414.8 = & 36.50 \text{ lbs.} & = \text{M.S.N.F. from milk} \\
5.8\% \text{ of } 252.6 = & 14.65 \text{ lbs.} & = \text{M.S.N.F. from cream} \\
32\% \text{ of } 152.7 = & \underline{48.86} \text{ lbs.} & = \text{M.S.N.F. from condensed skim.} \\
 & 100.01 \text{ lbs.} & \text{“checking” the M.S.N.F.}
\end{array}$$

The sugar, gelatin, and water for gelatin must be calculated in addition. This is a simple procedure. Multiply 1000 (the desired pounds of mix) by the percentage of sugar desired, 14.5. This gives 145, the pounds of sugar needed. The same simple method applies to the calculation of the 0.5% gelatin and the 3.0% of water for hydrating the gelatin.

This solution may seem long, because the substitutions have been made at length in the formulæ and all the steps in the process shown. After working out a few mixes in this way and being sure of the meaning of the formulæ, the shorter form given below should be used:

The formulæ or rules should be kept where they may be referred to quickly and the given numbers written down, as shown here.

To find $Z$:

$$\begin{array}{ll}
M = 1000 & \\
\left.\begin{array}{l} a = 4 \\ b = 35 \end{array}\right\} & 31 = b - a \\
c = 32 & \\
\left.\begin{array}{l} d = 8.8 \\ e = 5.8 \end{array}\right\} & 3.0 = d - e \\
\hline
10.5 \times 3 = 31.5 \ldots\ldots &
\end{array}
\qquad
\begin{array}{r}
31 \\
\times\ 10 \\
\hline
310 \\
+\ 31.5 \\
\hline
341.5 \\
-\ 233.5 \ldots\ldots \\
\hline
108.0
\end{array}
\qquad
\begin{array}{r}
35 \\
\times\ 8.8 \\
\hline
280 \\
280 \\
\hline
308.0 \\
-23.2 \ldots\ldots \\
\hline
284.8 = bd - ae \\
\times\ .82 \\
\hline
\left.\begin{array}{r} 22{,}784 \\ 570 \\ \hline 233.54 \end{array}\right\} *
\end{array}
\qquad
ae = \begin{array}{r} 5.8 \\ \times\ 4 \\ \hline 23.2 \end{array}$$

* Contracted multiplication.

$$\begin{array}{rr}
c(b - a) = & 31 \\
 & \times\ 32 \\
\hline
 & 992.0 \\
bd - ae = & 284.8 \\
\hline
 & 707.2 \ldots\ldots\ldots 707.2\overline{)108.0}(.1527 \text{ lbs.}
\end{array}$$

$1000 \times .1527 = 152.7$ lbs. condensed skim or $Z$.

To find $Y$:

$$
\begin{array}{rlll}
 & .82 & & \\
 & \times 4 & & \\
 & \overline{\phantom{0000}} & 10.5 & \\
.82a = & 3.28 \ldots\ldots\ldots & -\ 3.28 & \\
 & & \overline{\phantom{000000}} & \\
 & & 7.22 \times 1000 = & 7220.0 \\
 & aZ = & 4 \times 152.7 = & 610.8 \\
 & & & 31\overline{)7830.8}(252.6 \text{ lbs. cream or } Y.
\end{array}
$$

To find $X$:

$$
\begin{array}{rl}
10.5 \times 1000 = & 10{,}500 \\
35 \times 252.6 = & 8{,}841 \\
 & 4\overline{)\ 1{,}659}(414.8 \text{ lbs. milk, or } X.
\end{array}
$$

*Hint:* Study the short solution given above in connection with the rules.

**Rule 1.**—For finding $Z$, the amount of condensed skim.

*Step* 1.—Subtract the per cent of fat in the milk from the per cent of fat in the cream: $35 - 4 = 31$.

*Step* 2.—Multiply the result of Step 1 by the per cent of M.S.N.F. in the mix: $10 \times 31 = 310.0$.

*Step* 3.—Subtract the per cent of M.S.N.F. in the cream from the per cent of M.S.N.F. in the milk: $8.8 - 5.8 = 3.0$.

*Step* 4.—Multiply the result of Step 3 by the per cent of fat in the mix: $10.5 \times 3.0 = 31.5$.

*Step* 5.—Add the results of Steps 2 and 4: $310 + 31.5 = 341.5$.

*Step* 6.—Multiply the per cent of M.S.N.F. in the milk by the per cent of fat in the cream: $35.0 \times 8.8 = 308.0$.

*Step* 7.—Multiply the per cent of M.S.N.F. in the cream by the per cent of fat in the milk: $4.0 \times 5.8 = 23.2$.

*Step* 8.—Subtract the result of Step 7 from the result of Step 6: $308.0 - 23.2 = 284.8$.

*Step* 9.—Multiply the result of Step 8 by the per cent, expressed as a decimal, of dairy products in the mix (for standard used): $.82 \times 284.8 = 233.5$.

*Step* 10.—Subtract the result of Step 9 from the result of Step 5: $341.5 - 233.5 = 108.0$, which is the numerator of the formula.

*Step* 11.—Multiply the result of Step 1 by the per cent of M.S.N.F. in the condensed skim: $32 \times 31 = 992.0$.

*Step* 12.—Subtract the result of Step 8 from the result of Step 11: $992.0 - 284.8 = 707.2$.

*Step* 13.—Divide the result of Step 10 by the result of Step 12: $108.0 + 707.2 = .1527$.

*Step* 14.—Multiply the result of Step 13 by the number of pounds in the mix: $1000 \times .1527 = 152.7$ lbs. of Condensed Skim Required.

**Rule 2.**—For finding $Y$, the amount of cream required.

*Step* 15.—Multiply the per cent of fat in the milk by the per cent, expressed decimally, of dairy products in the mix: $.82 \times 4.0 = 3.28$.

*Step* 16.—Subtract the result of Step 15 from the per cent of fat in the mix: $10.5 - 3.28 = 7.22$.

*Step* 17.—Multiply the result of Step 16 by the number of pounds in the mix: $1000 \times 7.22 = 7220$.

*Step* 18.—Multiply the result of Step 14 (the amount of condensed skim required) by the per cent of fat in the milk: $4.0 \times 152.7 = 610.8$.

*Step* 19.—Add the results of Steps 18 and 17: $7220.0 + 610.8 = 7830.8$.

*Step* 20.—Divide the result of Step 19 by the result of Step 1 (Rule 1): $7830.8 \div 31 = 252.6$ lbs. of Cream Required.

**Rule 3.**—For finding $X$, the amount of milk required.

*Step* 21.—Multiply the per cent of fat in the mix by the number of pounds in the mix: $1000 \times 10.5 = 10{,}500$.

*Step* 22.—Multiply the result of Step 20 (the amount of cream required) by the per cent of fat in the cream: $35.0 \times 252.6 = 8841.0$.

*Step* 23.—Subtract the result of Step 22 from the result of Step 21: $10500 - 8841 = 1659$.

*Step* 24.—Divide the result of Step 23 by the per cent of fat in the milk: $1659 \div 4.0 = 414.8$ lbs. of Milk Required.

**Checks:** Check the results in the manner shown on page 140, which is, briefly, as follows:

Find the amount of fat and M.S.N.F. required for the mix, according to the standard used. Then find the amount of fat in the results obtained for all three ingredients, condensed skim, cream, and milk. These should agree closely with those required for the total mix.

Example IB (*Cream and Condensed Skim only*).—This is a simple mix, short and fast; and the correct results are obtained on the first calculation. To make 1000 lbs. of mix, using only cream and condensed skim (no whole milk) so that $a = 0$ and $d = 0$:

This problem comes under Case I, since $h$ and $k$ do not appear; and the formulæ for $Z$ and $Y$ become:

$$a = 0 \qquad b = 40 \qquad c = 30 \qquad d = 0 \qquad e = 5.4$$

$$Z = \frac{10b - 10.5e}{cb} \times M; \qquad Y = \frac{10.5M}{b}$$

Finding $Z$:

| | | |
|---|---|---|
| | 5.4 | 40 |
| | $10\frac{1}{2}$ | 30 |
| 40 | ——— | ——— |
| $\times 10$ | 540 | 1200 denominator |
| ——— | 27 | |
| 400 | ——— | |
| 65.1...... | 567 | |
| ——— | | |

343 ÷ 1200 = .2858

1000 × .2858 = 285.8 lbs. condensed skim

Finding $Y$:

10.5 × 1000 = 10,500

10,500 ÷ 40 = 262.5 lbs. cream

285.8 lbs. skim

———

548.3 lbs. dairy products

But, since only 18% of the mix is accounted for in the sugar, gelatin, and water, we must still account for 82% of it, or 820 lbs. Hence, we must add water enough to make this amount:

820
548.3
———
271.7 lbs. water to be added.

Example IC (*Maximum Amount of Cream*).—The maximum amount of cream will be used, assuming cream to be the only source of fat, and this problem is solved in Example IA above. Of course, if the cream is very rich, say 30 to 40%, water will have to be added. Example IB shows how to compute the amount of cream and condensed skim and how to find the amount of water to be added.

**Case II. Milk, Cream, Condensed Product.**—This is the most general case treated. Besides the ingredients considered in Case I, it involves the use of plain condensed whole milk, sweetened condensed whole milk, or sweetened condensed skim. The letters $a$, $b$, $c$, $d$, and $e$ are used with the same significance as in Case I.

But, since there may now be another source of fat (the condensed whole milk) and another source of sugar (the sweetened condensed, either whole or skim) the formulæ must provide for these also. Hence,

Let $h$ = % of fat in the plain condensed or sweetened condensed whole milk, if either of these be used. Otherwise, $h = 0$.

Let $K$ = 100% less the % of sugar in the sweetened condensed whole or skim, as the case may be. Thus, if the sweetened condensed contains 42% sugar, $k = 100\% - 42\%$, or .58.

As in Case I:

$X$ = No. lbs. of $a$% milk required.
$Y$ = No. lbs. of $b$% cream or butter required.
$Z$ = No. lbs. of $c$% condensed product required.

The General Formulæ follow:

$$Z = \frac{10(b - a) + 10.5(d - e) - .82(bd - ae)}{c(b - a) + h(d - e) - k(bd - ae)} \times M$$

$$Y = \frac{(10.5 - .82a)M + akZ - hZ}{b - a}$$

$$X = \frac{10.5M - bY - hZ}{a}$$

Example IIA (*Milk, Cream, Sweetened Condensed Skim*).—Using standard mix with ingredients having the following composition and computing at 1000-lb. mix:

Milk, 4%.
Cream, 40%.
Sweetened condensed skim milk, 32% M.S.N.F.
(Cane) sugar, 42%.

Thus

$M = 1000$
$a = 4$
$b = 40$
$c = 32$
$d = 8.6$
$e = 5.4$
$h = 0$ (since the fat in the skim milk is practically zero)
$k = .58$ (= 100% − 42%)

Computing $Z$ first:

$$Z = \frac{10(40 - 4) + 10.5(8.6 - 5.4) - .82(40 \times 8.6 - 4 \times 5.4)}{32(40 - 4) + 0(8.6 - 5.4) - .58(40 \times 8.6 - 4 \times 5.4)} \times 1000$$

$$= \frac{10 \times 36 + 10.5 \times 3.2 - .82 \times 322.4}{32 \times 36 + 0 - .58 \times 322.4} \times 1000$$

$$= \frac{360 + 33.6 - 264.4}{1152 - 187} \times 1000 = \frac{129{,}200}{965} = 133.9 \text{ lbs. of Sweetened Condensed Skim.}$$

$$Y = \frac{(10.5 - .82 \times 4) \times 1000 + 4 \times .58 \times 133.9 - 0 \times 133.9}{40 - 4}$$

$$= \frac{7220 + 310.6 - 0}{36} = \frac{7530.6}{36} = 209.2 \text{ lbs. Cream.}$$

$$X = \frac{10{,}500 - 8{,}368 - 0}{4} = \frac{2132}{4} = 533.0 \text{ lbs. Milk.}$$

Condensed computation of Example IIA.

(NOTE. The steps are performed in order according to the formulæ.)

Solving for $Z$ first:

$$\begin{array}{r}40\\-4\\\hline 36\\\times 10\\\hline 360\\33.6\\\hline 393.6\\264.4\\\hline 129.2\end{array}\qquad\begin{array}{r}8.6\\-5.4\\\hline 3.2\\\times 10\tfrac{1}{2}\\\hline 320\\16\\\hline 33.6\end{array}\qquad\begin{array}{r}8.6\\\times 40\\\hline 344.0\\-21.6\\\hline 322.4 = bd-ae\\\times .82\\\hline 25{,}792\\645\\\hline 264.37\end{array}\qquad\begin{array}{r}5.4\\\times 4\\\hline 21.6\end{array}$$

129.2 numerator of formula

Finding the value of the denominator:

$$\begin{array}{r}36\\\times 32\\\hline 72\\108\\\hline 1152\end{array}$$

Since any number times zero is zero the second term of the denominator is zero.

The third term is .58 times the $bd-ae$ already found, i.e., $.58\times 322.4 = 187.0$.

$1152-187=965$, the denominator

Dividing the numerator by the denominator,

$$129.2 \div 965 = .1339$$
$$1000 \times .1339 = 133.9 \text{ lbs. Sweetened Condensed Skim.}$$

Solving for $Y$:

$$\begin{array}{r}.82\\\times 4\\\hline 3.28\end{array}\qquad\begin{array}{r}10.5\\-3.28\\\hline 7.22\times 1000 = 7220\end{array}$$

$$\begin{array}{r}.58\\\times 4\\\hline 2.32\end{array}\qquad\begin{array}{r}133.9\\\times 2.32\\\hline 310.6\\7220.0\end{array}\qquad\begin{array}{r}40\\-4\\\hline 36\end{array}$$

$36\,)\,7539.6\,($ 209.2 lbs. of Cream

Check as before.

Solving for $X$:

$$\begin{array}{r}10.5\\\times 1000\\\hline 10{,}500.0\\8{,}368.0\\\hline 4\,)\,2{,}132.0\\533\end{array}\qquad\begin{array}{r}209.2\\\times 40\\\hline 8368.0\end{array}$$

533 lbs. of Milk.

$$\begin{array}{r}133.9\\\times 0\\\hline 00000\end{array}$$

Preliminary "check":

533.0 lbs. milk
209.2 lbs. cream
133.9 lbs. sweetened condensed skim
35.0 lbs. gelatin and water
88.8 lbs. sugar to be added (since the total amount of sugar is 145 lbs. and the 133.9 lbs. of condensed skim contains .42 × 133.9 or 56.2 lbs.) 145 − 56.2 = 88.8

99.9

The caution given in the footnote on page 140, about checking the results, should be heeded here also.

The complete check follows:

As in the "check" for Example 1,

10.5% of 1000 lbs. = 105 lbs. of fat required.

The sources of fat are the 4% milk and the 40% cream.

4% of 533.0 lbs. = 21.32 lbs. fat from milk
40% of 209.2 lbs. = 83.68 lbs. fat from cream.

105.00 lbs. total fat, which checks.

10% of 1000 = 100 lbs. of M.S.N.F. required.

The sources of M.S.N.F. are 8.6% from milk, 5.4% from cream, and 32% from sweetened condensed skim.

8.6% of 533.0 lbs. = 45.84 lbs. M.S.N.F. in milk.
5.4% of 209.2 lbs. = 11.30 lbs. M.S.N.F. in cream.
32% of 133.9 lbs. = 42.75 lbs. M.S.N.F. in sweetened condensed.

99.89 lbs. total M.S.N.F., which checks the required 100 lbs. near enough.

(It is probably superfluous to state that carrying the results out further would give a still closer check.)

EXAMPLE IIB (*Milk, Cream, Plain Condensed Whole Milk*).—To make 1000 lbs. of standard mix with the following ingredients:

Milk, 3.4% fat
Cream, 38% fat
Plain condensed whole milk $\begin{cases} 8\% \text{ fat} \\ 23\% \text{ M.S.N.F.} \end{cases}$

This example comes under Case II, but since the plain condensed whole milk contains no sugar, $k = 100\% - 0\% = 1$, so that the last term in the denominator of the formula is just $1(bd - ae) = bd - ae$.

In this mix there are three sources of fat and three sources of M.S.N.F. The greater the number of sources of fat and solids, the more difficult the "trial and error" method becomes.

Henceforth, only the short form of the solutions will be given. Finding $Z$ first, from table:

$a = 3.4$
$b = 38$
$c = 23$
$d = 8.7$ (Since 3.4 milk is nearly 3.5)
$e = 5.5$
$h = 8$
$k = 1$

$$bd = \left\{ \begin{array}{r} 38 \\ \times 8.7 \\ \hline 266 \\ 304\phantom{0} \\ \hline 330.6 \end{array} \right.$$

$$ae = \left\{ \begin{array}{r} 3.4 \\ \times 5.5 \\ \hline 170 \\ 170\phantom{0} \\ \hline 18.70 \end{array} \right.$$

$$\begin{array}{r} 8.7 \\ 5.5 \\ \hline 3.2 = d - e \\ 10\tfrac{1}{2} \\ \hline 320 \\ 16 \\ \hline 33.6 \end{array}$$

$$b - a = \left\{ \begin{array}{r} 38.0 \\ 3.4 \\ \hline 34.6 \\ \times 10 \\ \hline 346\phantom{.0} \\ +33.6 \\ \hline 379.6 \\ -255.8 \\ \hline \end{array} \right.$$

Numerator = 123.8

$$\begin{array}{r} 330.6 \\ -18.7 \\ \hline 311.9 = bd - ae \\ \times .82 \\ \hline 24{,}952 \\ 624 \\ \hline 255.76 \end{array}$$

$$\begin{array}{rr} b-a = & 34.6 \\ c = & \times 23 \\ \hline & 1038 \\ & 692\phantom{0} \\ \hline c(b-a) = & 795.8 \end{array}$$

$$\begin{array}{rr} d-e = & 3.2 \\ h = & \times 8 \\ \hline h(d-e) = & 25.6 \\ c(b-a) = & 795.8 \\ \hline & 821.4 \\ k(bd-ae) = & 311.9 \\ \hline & 509.5 \end{array}$$

$h(d-e) = 25.6$ and $c(b-a) = 795.8$: add

$k(bd-ae) = 311.9$ since $k = 1$

509.5 denominator

Dividing numerator by denominator,

123.8 ÷ 509.5 = .2430
1000 × .243 = 243 lbs. Condensed Milk = $Z$

**Finding $Y$:**

```
a=  3.4
   ×.82
   ----
   2.72
      7
   ----
   2.79 } Subtract
  10.50 }
  -----
   7.71
  ×1000
  -------
 7710.00 } add
  826.00 }
 --------
akZ = 8536.0 } subtract
      1944.0 }
     -------
hZ =  6592.0 = numerator
```

```
        243
       ×3.4
       ----
akZ =   972
       729
       ----
      826.2

hZ =    243
         ×8
       ----
       1944
```

$b - a = 34.6$ = denominator

6592 ÷ 34.6 = 190.52 lbs. Cream

**Finding $X$:**

```
 10.5 ×1000 = 10,500
190.52
  ×38
------
57,156
15,242
------
 7,239.8

10,500.0
 7,239.8
--------
 3,260.2

hZ = 3260.2
       1944
3.4)1316.2(387.1 lbs. Milk
```

Preliminary check:

.82 × 1000 = 820 lbs. dairy products.

```
243.0
190.5
387.1
-----
820.6 which checks nearly enough
```

Complete check:

| | |
|---|---|
| 3.4% of 387.1 lbs. = | 13.16 lbs. fat from milk |
| 38% of 190.5 lbs. = | 72.40 lbs. fat from cream |
| 8% of 243.0 lbs. = | 19.44 lbs. fat from condensed milk |
| | 105.00 check. |

10% of 1000 lbs. = 100 lbs. M.S.N.F. required.

Three sources; 8.7% in milk, 5.5% in cream, and 23% in condensed whole milk.

| | |
|---|---|
| 8.7% of 387.1 lbs. = | 33.67 lbs. from milk |
| 5.5% of 190.5 lbs. = | 10.48 lbs. from cream |
| 23% of 243.0 lbs. = | 55.89 lbs. from condensed whole |
| | 100.04 check. |

The most general problem under Case II arises when sweetened condensed whole milk is used. Then both $h$ and $k$ have special values in the formulæ.

EXAMPLE IIC (*Milk, Cream, and Sweetened Condensed Whole Milk*).—To make 1000 lbs. of standard mix using:

Sweetened condensed whole $\begin{cases} 8\% \text{ fat} \\ 23\% \text{ M.S.N.F.} \\ 40\% \text{ sugar} \end{cases}$

Milk 4%
Cream 35%

$$a = 4$$
$$b = 35$$
$$c = 23$$
$$\text{From Table} \begin{cases} d = 8.8 \\ e = 5.8 \end{cases}$$
$$h = 8.0$$
$$k = 100\% - 40\% = .60$$

Substituting in the general formulæ of Case II, page 145:

$$Z = \frac{10(35 - 4) + 10.5(8.8 - 5.8) - .82(35 \times 8.8 - 4 \times 5.8)}{23(35 - 4) + 8.0(8.8 - 5.8) - .60(35 \times 8.8 - 4 \times 5.8)} \times 1000$$

NOTE. The numerator for $Z$ is the same as in Example 1, page 140 and, hence, equals 108.0.

For the denominator:

| | | | |
|---|---|---|---|
| $b - a = \begin{cases} 35 \\ -4 \end{cases}$ | | | |
| | $d - e = \begin{cases} 8.8 \\ 5.8 \end{cases}$ | 35 | |
| 31 | | 8.8 | |
| 23 | | | |
| | 3.0 | 280 | |
| 93 | ×8 | 280 | 5.8 |
| 62 | | | ×4 |
| | 24.0 | 308.0 | |
| 713 .......... | 713.0 | 23.2 ....... | 23.2 |
| | 737.0 | 284.8 | |
| | | .60 | |
| | 170.9 .............. | 170.88 | |
| | 566.1 = denominator | | |

$108.0 \div 566.1 = .1908$
$1000 \times .1908 = 190.8$ lbs. Sweetened Condensed Whole

$$Y = \frac{(10.5 - .82 \times 4) \times 1000 + 4 \times .60 \times 190.8 - 8 \times 190.8}{35 - 4}$$

```
   .82
   ×4                              190.8
  ─────                             ×.6
  3.28                            ───────
  10.5                            114.48
  ─────                              ×4
  7.22×1000 = 7220.0              ───────
            + 457.9........457.92                  190.8
              7677.9                                 ×8
                                                  ───────
            −1526.4.............................1526.4
           31)6151.5(198.4 lbs. Cream
```

$$X = \frac{10.5 \times 1000 - 35 \times 198.4 - 8 \times 190.8}{4}$$

```
                      198.4
                       ×35
        10.5          ─────
        ×1000         5952
       ───────         992
       10500.0        ─────
        6944 ........ 6944        190.8
       ───────                      ×8
        3556                      ──────
        1526.4....................1526.4
      4)2029.6
       ───────
        507.4 lbs. Milk.
```

**Check.**—Here the sweet condensed whole includes sugar equal to 40% of 190.8 or 76.32. Hence, only 190.8 − 76.3 or 114.5 lbs. of it is strictly "dairy products."

Miscellaneous.—Under this head are classed those problems in which some of the ordinary ingredients are missing or given amounts of some of them are used.

114.5 + 198.4 + 507.4 = 820.3 lbs., which checks the 820 lbs. dairy products required

4% of 507.4 = 20.30 lbs. from milk
8% of 190.8 = 15.25 lbs. from sweet condensed whole
35% of 198.4 = 169.44 lbs. cream
105.00 lbs., which checks fat needed
8.8% of 507.4 = 44.65 lbs. from milk
23% of 190.8 = 43.88 lbs. from condensed whole
5.8% of 198.4 = 11.51 lbs. from cream.
100.04 lbs., which checks M.S.N.F. needed.

Example IIIA (*Condensing Ingredients Added to the Pan and Condensed*). Where proper facilities are available, ice cream mixes are sometimes made by the vacuum-pan method. Mojonnier and Troy make the following statement with regard to this process:

> By the process a superior quality product can be obtained, besides the numerous economic advantages. The temperatures during no part of the operation are allowed to exceed 140° F., so that the natural flavors are fully retained. The temperature used in condensing the mix is the same as that used in pasteurizing, therefore the pasteurizing and condensing are combined in one operation. The principles involved are the same as in the case of other dairy products. The whole milk, butter or cream, sugar and the gelatin are all added in the hotwells, and condensed together in the vacuum pan.[6]

The authors did considerable work by this method at the California station and obtained an excellent grade of ice cream, giving special attention to the condensing pan. The quality of the cream was in no way superior, though it was equal to the product made by condensing only the skim-milk and preparing the mix in the usual way.

The mix is first made up larger than it should be finally, and is then condensed. Since no condensed product enters into this mix, there is no formula for $Z$. The formulæ for $X$ and $Y$ follows:

$$X = \frac{10b - 10.5e}{bd - ae} \times M \qquad Y = \frac{10.5d - 10a}{bd - ae} \times M$$

where the letters have the usual meanings, as explained on page 139.

To make 1000 lbs. of standard mix, using 4% milk and 40% cream and condensing down, thus:

$a = 4$

$b = 40$

$c = 0$ (does not appear)

$\left.\begin{array}{l} d = 8.8 \\ e = 5.35 \end{array}\right\}$ From Table

Substituting in the formulæ for $X$ and $Y$:

$$X = \frac{10 \times 40 - 10.5 \times 5.35}{40 \times 8.8 - 4 \times 5.35} \times 1000 = \frac{400 - 56.17}{352 - 21.4} \times 1000$$

$$= \frac{343.83}{330.6} \times 1000 = 1040 \text{ lbs. Milk}$$

$$Y = \frac{10.5 \times 8.8 - 10 \times 4}{330.6} \times 1000 = \frac{92.4 - 40}{330.6} \times 1000$$

$$= \frac{52.4}{330.6} \times 1000 = 158.5 \text{ lbs. Cream}$$

1040 lbs. milk
158.5 lbs. cream
180 lbs. sugar, gelatin and water (= 18% of 1000 lbs.)
1378.5 total to be condensed down to 1000 lbs.

[6] Moyjonnier and Troy, Technical Control of Dairy Products, pp. 717–718.

Example IVA (*Cream, Skim and Condensed Skim*).—To make 1000 lbs. standard mix with the following ingredients:

30% cream.
Plain skim, 8.9% M.S.N.F.
32% condensed skim.

The formulæ of Case I, page 139, are used, where the skim milk takes the place of the whole milk.

Hence,

$$\begin{aligned} a &= 0 \\ b &= 30 \\ c &= 32 \\ d &= 8.9 \\ e &= 6.2 \end{aligned} \Big\} 2.7 = d - e$$

The formulæ become:

$$Z = \frac{10b + 10.5(d - e) - .82bd}{b(c - d)} \times M$$

$$Y = \frac{10.5M}{b}$$

$$X = .82M - (Y + Z).$$

Substituting in the formulæ,

$$Z = \frac{10 \times 30 + 10.5 \times 2.7 - .82 \times 30 \times 89}{30(32 - 8.9)} \times 1000$$

| | | | |
|---|---|---|---|
| | 10.5 | 82 | |
| | 2.7 | 30 | |
| 30 | | | 32.0 |
| 10 | 735 | 24.60 | 8.9 |
| | 210 | 8.9 | |
| 300 | | | 23.1 |
| 28.35...... | 28.35 | 2214 | ×30 |
| | | 1968 | |
| 328.35 | | | Denominator 693.0)109.41(.1579 |
| 218.94................ | | 218.94 | |
| | | | 1000 × .1579 = 157.9 or 158 lbs. Condensed Skim. |
| 109.41 numerator | | | |

Finding $Y$:

$$Y = \frac{10.5 \times 1000}{30} = \frac{10{,}500}{30} = 350 \text{ lbs. Cream}$$

| | |
|---|---|
| 350 | $.82 \times 1000 = 820$ |
| +158 | $X = 820 - 508 = 312$ lbs. Skim |
| 508 lbs. | |

**Check:** 30% of 350 lbs = 105 lbs. fat from cream, which checks, as the cream is the only source of fat.

$$\text{M.S.N.F.}\begin{cases} 6.2\% \text{ of } 350 \text{ lbs.} = 21.70 \text{ from cream.} \\ 8.9\% \text{ of } 312 \text{ lbs.} = 27.77 \text{ from skim.} \\ 32\% \text{ of } 158 \text{ lbs.} = 50.56 \text{ from condensed skim.} \end{cases}$$

100.03 lbs. total, which checks 100 lbs. required.

Example VA (*Left-overs*).—A plant may have a certain amount of cream or milk, or both, left over, which must be used in the mix.

To make 1000 lbs. standard mix using:

60 lbs. left-over 35% cream,
50 lbs. left-over 20% cream,
150 lbs. left-over 4% milk,

and enough 3.8% milk and 40% cream and 30% condensed skim to make the mix. It is necessary to find first how much fat and M.S.N.F. are contained in the milk and cream left over, which must go into the mix.

35% of 60 lbs. = 21.0 lbs. of fat from cream,
20% of 50 lbs. = 10.0 lbs. of fat from cream,
3.8% of 150 lbs. = 5.7 lbs. of fat from milk.

36.7 lbs. fat accounted for.

10.5% of 1000 = 105.0 lbs. fat required altogether.
105.0 lbs. − 36.7 = 68.3 lbs. still needed.
68.3 ÷ 1000 = .0683 or 6.83%; that is, the fat still needed equals 6.83% of the 1000 lbs. mix.

Hence, the 6.8% (close enough) takes the place of the old 10.5 in the formulæ of Case I.

Similarly, for M.S.N.F.,

5.8% of 60 lbs. = 3.48 M.S.N.F. from cream.
7.1% of 50 lbs. = 3.55 M.S.N.F. from cream.
8.8% of 150 lbs. = 13.20 M.S.N.F. from milk.

20.23 = M.S.N.F. accounted for.

10% of 1000 lbs. = 100 lbs. M.S.N.F. required altogether.
100 − 20.23 = 79.77 or 80 lbs. M.S.N.F. still needed.
80 ÷ 1000 = .080 or 8%.

Hence, the 8.0 takes the place of the old 10 in the formulæ.

Now, as usual with the standard mix, 82% of it consists of dairy products amounting to 820 lbs. The 60 + 50 + 150 to be used amounts to 260 lbs.

Hence, 820 lbs. − 260 lbs. or 560 lbs., equals the amount still needed. 560 ÷ 1000 = .56, which takes the place of the old 0.82 in the formulæ.

Hence, the formula for $Z$, Case I, page 139, is:

$$Z = \frac{8.(b-a) + 6.3(d-e) - .56(bd-ae)}{c(b-a) - (bd-ae)} \times M$$

$$Y = \frac{(6.8 - .56a)M + aZ}{b-a}$$

$$X = \frac{6.8M - bY}{a}$$

The problem now is to find how much of the 3.8% milk, 40% cream, and 30% condensed skim must be used to make up the 560 lbs. still needed. This is done by substituting the proper values of $a$, $b$, etc., in the formulæ as written above.

In this particular example;

$a = 3.8$
$b = 40$
$c = 30$
From Table $\begin{cases} d = 8.8 \\ e = 5.35 \end{cases}$

$$bd = \left\{ \begin{array}{r} 8.8 \\ \times 40 \\ \hline 352.0 \end{array} \right.$$

$$ae = \left\{ \begin{array}{r} 5.35 \\ \times 3.8 \end{array} \right.$$

$$\begin{array}{r} \hline 1605 \\ 428 \\ \hline 20.33 \\ \\ 352.0 \\ -20.3 \\ \hline 331.7 = bd - ae \\ \times .56 \\ \hline 16585 \\ 1990 \\ \hline 185.75 \end{array}$$

$$d - e = \left\{ \begin{array}{r} 8.80 \\ 5.35 \\ \hline 3.45 \end{array} \right.$$

$$\begin{array}{r} 3.45 \\ \times 6.8 \\ \hline 2070 \\ 276 \\ \hline 23.46 \end{array}$$

$$\begin{array}{r} 40.0 \\ 3.8 \\ \hline 36.2 \\ \times 8 \\ \hline 289.6 \\ +23.5 \\ \hline 313.1 \\ 185.75 \\ \hline 127.35 \end{array}$$

127.35 = numerator

Finding denominator:

$$c(b-a) = \begin{cases} 36.2 \\ \times 30 \end{cases}$$

$$\begin{array}{rr} & 1086.0 \\ bd - ae = & 331.7 \\ \hline & 754.3 = \text{denominator.} \end{array}$$

(127.35 ÷ 754.3) 1000 = 168.8 lbs. Condensed Skim Required

Finding $Y$:

$$\begin{array}{rr} .56 & 168.8 \\ 3.8 & 3.8 \\ \hline 168 & 5064 \\ 45 & 1350 \\ \hline 2.13 & 641.4 \end{array}$$

$$\begin{array}{r} 6.80 \\ 2.13 \\ \hline 4.67 \times 1000 = 4670.0 \\ 641.4 \end{array}$$

$$b - a = 36.2\overline{)5311.4}(146.7 \text{ lbs. Cream}$$

Finding $X$:

$$6.8 \times 1000 = 6800.0$$

$$bY = 40 \times 146.7 = 5868.0$$

$$\begin{array}{r} 6800.0 \\ -5868.0 \end{array}$$

$$3.8\overline{)\ 932.0}(245.3 \text{ lbs. Milk}$$

Check
245.3
146.7
168.8

560.8 lbs., which checks the 560 lbs. needed (near enough)

Fat
40% of 146.7 = 58.68 from cream
3.8% of 245.3 = 9.32 from milk

68.00 total, which checks the 68.3 lbs. needed:

30% of 168.8 = 50.65 lbs. from skim
5.35% of 146.7 = 7.85 lbs. from cream
8.8 % of 245.3 = 21.60 lbs. from milk

80.10 lbs. total

M.S.N.F. which checks the 80 lbs. needed.

EXAMPLE VIA (*Using a Given Amount of Sweet Butter and Cream*).—To make 1000 lbs. of standard mix, using:

100 lbs. sweet butter, 83% fat,
50 lbs. 25% cream with enough 40% cream (no whole milk) and 32% condensed skim to make the mix.

It is necessary first to find how much fat and M.S.N.F. the given ingredients contain, then to find how much must be furnished by the unknown 40% cream and condensed skim.

83% of 100 lbs. = 83 lbs. fat in the butter
25% of 50 lbs. = 12.50 lbs. fat in the 25% cream

95.5 lbs. fat in both

10.5% of 1000 lbs. = 105 lbs. in the mix
105 − 95.5 = 9.5 lbs. fat still needed

Since this 9.5 lbs. of fat is to come from 40% cream, 9.5 ÷ 0.40 = 23.75 lbs. of 40% cream needed

100 + 50 + 23.75 = 173.8 lbs. total cream and butter.

Now, in order to use the formulæ, it is necessary to find what this cream and butter test, both in fat and M.S.N.F.

105 ÷ 173.8 = 60.4% fat = $b$ in the formula.

The 25% cream tests 6.68% or 6.7% M.S.N.F. by the table and the 40% cream tests 5.35%.

6.7% of 50 lbs. = 3.35 lbs. M.S.N.F. in 25% cream
5.35% of 23.75 = 1.27 lbs. M.S.N.F. in 40% cream

Total = 4.62 lbs. M.S.N.F. in cream and butter.

Now, since no milk is used, $a$ and $e$ are zero (= 0).
Hence,

$$a = 0$$
$$b = 60.4$$
$$c = 32$$
$$d = 0$$
$$e = 2.65$$

$Y$, the cream and butter, is already known, namely 173.8 lbs., and the formula for $Z$ becomes:

$$Z = \frac{10b - 10.5e}{cb} \times M$$

Substituting the new values of $b$ and $e$ in the formulæ for $Z$,

$$Z = \frac{10 \times 60.4 - 10.5 \times 2.65}{32 \times 60.4} \times 1000$$

```
                       26.5              60.4
                       10½                 32
60.4                   ----              ------
  10                   26.5              1208
------                  1.32             1812
604.0                  ----              ------
 27.82..........27.82                    1932.8 = denominator
------
Numerator 576.18
```

576.18 ÷ 1932.8 = .298
1000 × .298 = 298 lbs. condensed skim
Check as usual.

EXAMPLE VIIA (*Given Amounts of Two or More Ingredients*).—This is a special problem in which given amounts of two or three ingredients are used, and which can be solved without either the algebraic formulæ or the trial and error method.

To make 1000 lbs. of standard mix with the following given amounts of milk and cream:

200 lbs. of 4% milk
100 lbs. of 3% milk
100 lbs. of 35% cream and enough 40% cream and 30% skim to make the mix.

*Solution:*

4% of 200 lbs. = 8 lbs. fat
3% of 100 lbs. = 3 lbs. fat
35% of 100 lbs. = 35 lbs. fat
—
46 lbs. fat in given ingredients.

105 lbs. − 46 lbs. = 69 lbs. fat still to come from 40% cream
69 ÷ .40 = 172.5 lbs. of 40% cream needed.

8.8% of 200 lbs. = 17.6 lbs. from 4% milk
8.6% of 100 lbs. = 8.6 lbs. from 3% milk
5.8% of 100 lbs. = 5.8 lbs. from 35% cream
5.35% of 172.5 lbs. = 9.2 lbs. from 40% cream
—
41.2 lbs. provided for.

100 lbs. − 41.2 = 58.8 lbs. M.S.N.F. still to come from condensed skim testing 30%. 58.8 lbs. ÷ 0.30 = 196 lbs. Condensed Skim.

Hence, 172.5 lbs. of 40% cream and 196 lbs. of condensed skim are needed in addition to the given ingredients.

EXAMPLE VIIIA. *Other Standards.*—The formulæ and rules given above can be applied to standard mixes other than the one used thus far in this chapter.

*Example;* To make 1000 lbs. (or any other amount) of mix which shall contain the following:

12% fat
11% M.S.N.F.
14% sugar
0.5% gelatin with no water

14% sugar + 0.5% gelatin = 14.5%

Hence, the dairy products must constitute 100% − 14.5% = 85.5%, or .855 of the mix, and the numbers 12, 11, and 0.855 simply take the place of 10.5, 10 and 0.82 in the formulæ of Case I and Case II. Thus the formulæ of Case I become:

$$Z = \frac{11(b - a) + 12(d - e) - .855(bd - ae)}{c(b - a) - (bd - ae)} = M$$

where $a$, $b$, $c$, etc., have the same meaning as in previous examples, and $M$ is 1000 or 750 or any other amount of mix desired.

$$Y = \frac{(12 - .85a)M + aZ}{b - a}$$

$$X = \frac{(12M - bY)}{a}$$

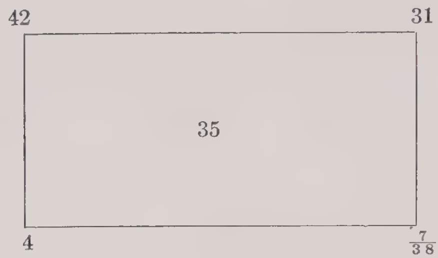
The rules on pages 142 to 143 apply here also.

Thus, in Step 2, the result of Step 1 is multiplied by 11 under this standard, instead of 10; and in Step 9, the result of Step 8 is multiplied by 0.855 instead of 0.82, and so on.

**Pearson Method.**—Often the simplest method of calculating a new mix is to standardize the milk and cream to a definite percentage. No simpler and more accurate method can be used than that devised by Dr. R. A. Pearson some years ago, and known as the "rectangle" method. To use this method, draw a rectangle. At the upper left-hand corner place the percentage of fat in the cream to be cut down. At the lower left-hand corner put the percentage of fat in the milk used to reduce the fat in the cream. It may be that skim milk is to be used. In such a case, "0% fat" would appear at this corner of the rectangle. In the center of the rectangle is placed the percentage of fat desired. Work

diagonally across the square, subtracting the smaller number from the larger, and record the differences at the opposite corners.

For example: It is desired to reduce the fat in 42% cream to 35%, using 4% milk. 1000 lbs. of 35% cream is desired.




$7/38 \times 1000$ = lbs. of 4% milk = 184.2 lbs.
$31/38 \times 1000$ = lbs. of 42% cream = 815.8 lbs.

The same method can be used in standardizing milk, acid for testing dairy products, etc.

In the above case, if only a certain quantity of cream is used and all is to be used, 31/38 would equal that amount. The same principle would apply to milk or any other product where similar standardization is involved.

The mixes calculated by the algebraic method in the preceding pages may often be made use of, by standardizing the cream, milk, and condensed (or whatever products may be used) to the percentages given. Illustrating the mix calculated on pages 139–140 for 1000 lbs., using:

4% milk
35% cream
32% condensed skim

in which it requires 414.8 lbs. of milk, 252.6 lbs. of cream and 152.7 lbs. of condensed skim. The standard upon which this mix was made required 10.5% fat, 10% M.S.N.F., 14.5% sugar, and 0.5% gelatin.

Assuming that the milk on hand tested 3.5% butterfat, the cream 40% butterfat, and the condensed skim 35% total solids, and that skim milk is available for reducing the fat in the cream from 40% to 35%, the following simple calculation is sufficient:

252.6 (lbs. of cream needed) $\times$ 35/40 = 221.02 lbs. of 40% cream required
252.6 − 221.02 = 31.4 lbs. of skim milk required.

The same method applies in cutting the condensed from 36% total solids to 32% total solids. 152.7 (lbs. of condensed needed) × 32/36 = 135.7 lbs. of 36% condensed required.

$$152.7 - 135.7 = 17.0 \text{ lbs. of water.}$$

In the case of the milk, the fat is to be increased from 3.5 to 4%. The Pearson method, already described, is a convenient one. 414.8 lbs. of 4% milk is needed, using 40% butterfat cream and 3.5% butterfat milk as the base.

| | | |
|---|---|---|
| 40 | | 0.5 parts of 40% cream |
| | 4.0 | |
| 3.5 | | 36.0 parts of 3.5% milk |
| | | 36.5 common denominator |

$$414.8 \times \frac{.5}{36.5} = 5.68 \text{ pounds of } 40\% \text{ cream}$$

$$414.8 \times \frac{36}{36.5} = \frac{409.22}{414.90} \quad \text{total.}$$

The above calculations have been carried out in fractions of pounds. In actual practice the nearest pound would be accurate enough. Only in very small mixes would the test be affected. This method could be used for the cream and condensed instead of the one illustrated.

## CHAPTER VII

# PROCESSING

Every ice cream manufacturer should have some standard for his product. Once a standard is selected, changes should be made only after mature deliberation. The adoption of a standard, however, by no means assures the quality of the product. It is only the first essential. The second is to secure the necessary ingredients of the right quality. The manufacturer must then see that these are properly combined according to the standard adopted, and then processed skillfully, keeping in mind the complexity of the product that is being built—one of true solutions, colloidal solutions, suspensions, and emulsions, having true, apparent and basic viscosity. The quality of the product is greatly affected by the chemical and physical treatment. Before processing can begin, certain determinations should be made, one of which is that of the acidity of the dairy products to be used. (See Acid Test.)

**Acidity of the Mix.**—In years gone by, acid in the mix was considered desirable, and a small amount is usually present. Too much acidity is associated with poor quality of raw materials. The presence of an excessive amount does not necessarily mean off-flavors in the dairy products, but lack of care that permits the development of acid is usually accompanied by other forms of carelessness and, consequently, off-flavors are nearly always present. The amount of acid in the mix also depends upon the percentage of milk solids-not-fat that it contains. To set a standard amount of acid for each mix would be impossible, if the percentage of milk solids-not-fat varied, all other things being equal. Lactic acid, which is formed by bacterial action, is contained in the milk serum; therefore the percentage of fat in the product influences the amount of acid present. For that reason, the 35 per cent cream containing 5.8 per cent milk solids-not-fat contains less acid than does the whole milk from which the cream was obtained. Skim-milk, to be condensed in the pan, may have an acidity of 0.18 of 1 per cent when drawn in; during the condensing process, the temperature is high enough to prevent further development, yet the acid will be much higher in the finished condensed. Lactic acid is only slightly volatile and is therefore concentrated along with the other solids, the

amount depending upon the degree of concentration. Skim-milk powder contains still more acid. The initial acidity may be quite accurately determined by figuring back from the degrees of concentration, thereby gaining some insight into the original acidity of the product. Good mixed milk as received by a plant should contain not more than 0.16 per cent of acid. If special care is given in selecting and processing the dairy products, the ice cream mix should normally contain 0.018 per cent of acid for each per cent of milk solids-not-fat. A 10 per cent milk solids-not-fat mix should, therefore, normally contain 0.18 per cent of acid. It is quite difficult, however, in actual practice, to construct a 10 per cent milk solids-not-fat mix and obtain much less than 0.20 per cent acid.

With the following table, in terms of lactic acid, Dahle[1] illustrates the influence of the titratable acidity of the materials used upon the acidity of the mix.

TABLE XXXV

| Ingredients | Pounds | Per Cent Acidity | Pounds of Acid | Acidity as Calculated | Acidity as Determined by Mann's Test |
|---|---|---|---|---|---|
| 39% cream......... | 381 | 0.1275 | 0.48577 | | |
| 35% cream......... | 218 | 0.115 | 0.25070 | | |
| Plain condensed skim | 453 | 0.5205 | 2.27632 | | |
| Skim-milk.......... | 472 | 0.2175 | | | |
| Sugar.............. | 270 | | | | |
| Gelatin............ | 6 | | | | |
| Total.......... | 1800 | ........ | 4.0394 | 0.2242 | 0.225 |

This mix contained 10 per cent milk solids-not-fat. The acidity of the products used could well be considered average and of good quality, with the possible exception of the skim-milk. The table shows, as would be expected, that the acidity can be calculated from the ingredients used, to conform to the acidity of the combined ingredients.

Some investigators claim that lactic acid tends to increase viscosity. P. H. Tracy[2] and B. Masurovsky[3] disagree as to the effect of lactic

[1] Dahle, C. D., Ice Cream Trade Journal, December, 1926, p. 49.
[2] Tracy, P. H., Ice Cream Review, April, 1926, p. 92.
[3] Masurovsky, B., Journal of Dairy Science, Vol. 6, p. 591, 1923.

acid on viscosity. Work done by the authors substantiates the conclusion of Tracy. Acid did not develop when the aging temperature was maintained at the proper degree, but viscosity developed even faster than when the duplicate mixes were held at higher temperatures. (See Aging.) This is explained under the discussion of colloids.

Too much acid decreases slightly the possible yield, although, under good practical processing conditions, more yield can be obtained than is necessary or desirable for good ice cream. In addition, the increase in acid produces a cream that is more open, rougher, and less resistant to heat. Neutralizing high-acid mixes (0.23 of 1 per cent or above) to 0.2 of 1 per cent improved the texture and increased the resistance to heat. The resulting ice cream was closer in body. The most desirable product contained an acidity of 0.18–0.20 of 1 per cent. The milk solids-not-fat varied from 10 to 12 per cent.

**Effect of Neutralization.**[3a]—Manufacturers have come to recognize the fact that too much acid is undesirable, and in some instances have used such reducing agents as sodium bicarbonate to standardize the acid to 0.18–0.20 of 1 per cent. Whether the acid is standardized or not, the pressure and acidity at which the mix is homogenized should have a certain definite relationship. The average acidity of some of the products used in the manufacture of ice cream is as follows:

| | |
|---|---|
| Milk | 0.16–0.18 per cent |
| Plain condensed skim | 0.5 –0.6 |
| Butter | 0.05–0.30 |
| Cream | 0.11–0.15 |
| Fluid skim-milk | 0.16–0.20 |
| Sweetened condensed, whole | 0.5 –0.6 |
| Sweetened condensed, skim | 0.5 –0.6 |
| Skim-milk powder | 1.6 |

Two kinds of acidity are usually present in butter: true acidity (measured by hydrogen-ion concentration), and apparent acidity (measured by Mann's Acid Test). The neutralizers generally allowed for these are calcium hydrate, milk of magnesium, sodium acid carbonate, sodium carbonate, and calcium carbonate.

Turnbow and Milner[4] studied the effect of various neutralizers upon viscosity.

[3a] The authors do not believe in or recommend the practice of neutralization to conceal inferiority in raw materials. The following discussion is presented for the sake of completeness.

[4] Turnbow, G. D., and Milner, F. W., University of California Agr. Exp Sta. Unpublished work.

TABLE XXXVI

EFFECT OF NEUTRALIZATION UPON VISCOSITY

| Sample | Acidity | Neutralizer | Final Acidity | Gelatin Added | Viscosity, Poises |
|---|---|---|---|---|---|
| 1 | 0.362 | $Ca(OH)_2$ | 0.125 | After Hom. | 21.84 |
| 2 | 0.358 | MgO | 0.195 | After Hom. | 15.6 |
| 3 | 0.380 | $NaHCO_3$ | 0.240 | After Hom. | 14.5 |
| 4 | 0.350 | $Na_2CO_3$ | 0.200 | After Hom. | 20.2 |
| 5 | 0.347 | None | 0.375 | After Hom. | 7.28 |
| a | 0.240 | $Ca(OH)_2$ | 0.120 | Before Hom. | 36.4 |
| b | 0.255 | MgO | 0.170 | Before Hom. | 12.48 |
| c | 0.460 | $NaHCO_3$ | 0.160 | Before Hom. | 13.0 |
| d | 0.250 | $Na_2CO_3$ | 0.160 | Before Hom. | 12.48 |
| e | 0.241 | $Ca(OH)_2$ | 0.140 | Before Hom. | 25.48 |
| f | 0.235 | MgO | 0.165 | Before Hom. | 10.92 |
| g | 0.250 | $NaHCO_3$ | 0.150 | Before Hom. | 8.32 |
| S | 0.205 | None | 0.205 | Before Hom. | 9.88 |

The data show that the addition of a neutralizer to the ice cream mix has in every case brought about a change in viscosity. In sample No. 5, the acidity was allowed to develop and was not neutralized. The viscosity in this case was less than in the same mix, No. S, which was aged at a temperature that did not permit the acid to develop. In No. 5, the acidity tended to destroy the viscosity. It will be noted that in many cases the acid was reduced quite low, in fact so low as to injure the flavor of the product. In the following table[5] a wider range was allowed and the flavor was impaired only when the acidity was reduced below 0.18 of 1 per cent.

TABLE XXXVII

NEUTRALIZATION AND VISCOSITY

| Sample | Acidity | Neutralizer | Final Acidity | Gelatin Added | Viscosity, Poises |
|---|---|---|---|---|---|
| 1 | 0.250 | $Ca(OH)_2$ | 0.125 | Before | 17.16 |
| 2 | 0.242 | MgO | 0.1885 | Before | 12.48 |
| 3 | 0.250 | $NaHCO_3$ | 0.190 | Before | 11.44 |
| 4 | 0.235 | $Na_2CO_3$ | 0.120 | Before | 17.16 |
| 5 | 0.250 | None | 0.250 | Before | 11.96 |
| 6 | 0.240 | $Ca(OH)_2$ | 0.100 | Before | 21.36 |
| 7 | 0.250 | MgO | 0.154 | Before | 11.44 |
| 8 | 0.235 | $NaHCO_3$ | 0.180 | Before | 11.96 |
| 9 | 0.242 | $Na_2CO_3$ | 0.095 | Before | 36.40 |
| 10 | 0.230 | None | 0.230 | Before | 12.48 |
| S | 0.205 | None | 0.205 | Before | 9.88 |

[5] Turnbow, G. D., and Milner, F. W., University of California Agr. Exp. Sta., Unpublished work.

The increase in viscosity follows the same curve as in the preceding table. It is shown to have depended upon the kind and amount of neutralizer added. It is to be noted that none reached neutrality. In all colloidal solutions, there are specific effects caused by the addition of certain salts. It is known that some salts decrease the viscosity, while others increase it and still others exert no influence whatsoever. Neutralizers naturally would lower the freezing point. They go into solution, as shown by Parfitt's work, in which sodium bicarbonate was used:

TABLE XXXVIII

Effect of Neutralizer (Sodium Bicarbonate) on Freezing Point

| Freezing Point | Per Cent Lactic Acid | Per Cent Total Solids | Per Cent Serum Solids | Per Cent Fat |
|---|---|---|---|---|
| ° C | | | | |
| −2.4 | 3.4 | 34.3 | 12.4 | 8.7 |
| −2.9 | 2.0 | 34.3 | 12.4 | 8.7 |

Wilson[6] states that, because of their amphoteric properties, protein colloids have a tendency to absorb hydrogen ion and hydroxyl ion. These absorbed ions form a double layer on the walls or pores on the interior of the protein. This adsorption of the ions tends to influence the swelling and imbibition of water, by electrolytic repulsion. Salts may furnish ions that neutralize the electro-field of absorbed layers, causing a reduction of the swelling. It appears that the addition of neutralizers and salts neutralize to some extent the electro-field of adsorbed acid and makes it possible for more acid to reach the wall, with increased adsorption. An increase in adsorption is accompanied by an increase in viscosity.

## NEUTRALIZATION

Neutralization is based upon the addition of an alkali solution to neutralize the excess acid in the mixture. The amount of alkali solution to be added depends upon the amount of acid to be neutralized. Since this is determined by the quantity of the mixture and its acidity test, these factors are so important that any inaccuracy in them will defeat the purpose of neutralization.

The acidity may be determined by any method, provided accurate results are obtained.[7] The kind of neutralizer or alkali solution to

[6] Wilson, 3rd report of colloidal chem. London. P. 54.

[7] For acidity analysis, see pp. 299 to 302.

be used is also a matter of choice. The common ones, however, are hydrate of calcium, oxide of calcium and of magnesium (quicklime and magnesia lime), and bicarbonate of soda (baking soda).

In calculating the amount of neutralizer to add, it is necessary to determine (1) what neutralizer will be used, (2) the desired acidity of the mixture, (3) the original acidity of the mixture, (4) the total quantity of the mixture, and (5) the strength of the neutralizer solution.

Once these facts are known, it becomes an easy matter to determine the amount of neutralizer to add, as will be seen in the following example:

Suppose that a 2000-lb. mix tests 0.28 per cent acid and must be neutralized with sodium bicarbonate to 0.20 per cent acid. By subtraction ($0.28 - 0.20 = 0.08$ per cent) it appears that there is 0.08 per cent acid, or 0.08 lb. of excess acid in each 100 lbs. of mix. Therefore, there are 2000 (weight of mix) times 0.08 lb. = 1.6 lbs. of lactic acid to be neutralized.

Pure sodium bicarbonate is univalent and has a molecular weight of 84, while that of pure lactic acid is 90. It will take 84 lbs. of pure sodium bicarbonate, therefore, to neutralize 90 lbs. of pure lactic acid. The amount required to neutralize 0.01 lb. of pure lactic acid (0.01 lb. in 100 lbs. of mix) is $90 : 84 = .01 : x$. $x = 0.00933$ lb. dry sodium bicarbonate. 1.6 lbs. of lactic acid will require $160 \times 0.00933 = 1.4928$ lbs. of dry sodium bicarbonate. This can be weighed directly into a flour sprinkler, dissolved in four times its weight of water, and added directly to the ice cream mix. If a solution of sodium bicarbonate is already prepared, it is necessary to add that quantity of solution which will contain 1.4928 lbs. of dry sodium bicarbonate.

## Specific Directions for Neutralization

1. A neutralizing solution is made up to the proper strength.

2. The ice cream mix is warmed to 90° F. (100° F., if butter is used), and held at that temperature until the neutralizer has had time to complete its action, usually five or ten minutes.

3. The neutralizing solution is thoroughly agitated to insure a homogeneous mixture. The required amount of neutralizer is measured into a gallon measure graduated to half pints as indicated by the neutralization table.

4. The solution is strained through a cheese cloth into a flour sprinkler pot, and an equal amount of water added and thoroughly mixed.

5. The ice cream mix is kept well agitated while the neutralizer is being sprinkled over it in all parts of the vat.

TABLE LXXVIII

NEUTRALIZING TABLE—POUNDS OF DRY BICARBONATE OF SODA REQUIRED TO REDUCE ACIDITY TO 0.20 PER CENT

| Pounds of Ice Cream Mix | Per Cent Acidity in Mix | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .21 | .22 | .23 | .24 | .25 | .26 | .27 | .28 | .29 | .30 | .31 | .32 | .33 | .34 | .35 |
| 1000 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .7 | .8 | .9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 |
| 1100 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 |
| 1200 | .1 | .2 | .3 | .4 | .6 | .7 | .8 | .9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.5 | 1.6 | 1.7 |
| 1300 | .1 | .2 | .4 | .5 | .6 | .7 | .8 | 1.0 | 1.1 | 1.2 | 1.3 | 1.5 | 1.6 | 1.7 | 1.8 |
| 1400 | .1 | .3 | .4 | .5 | .7 | .8 | .9 | 1.0 | 1.2 | 1.3 | 1.4 | 1.6 | 1.7 | 1.8 | 2.0 |
| 1500 | .1 | .3 | .4 | .6 | .7 | .8 | 1.0 | 1.1 | 1.3 | 1.4 | 1.5 | 1.7 | 1.8 | 2.0 | 2.1 |
| 1600 | .1 | .3 | .4 | .6 | .7 | .9 | 1.0 | 1.2 | 1.3 | 1.5 | 1.6 | 1.8 | 1.9 | 2.1 | 2.2 |
| 1700 | .2 | .3 | .5 | .6 | .8 | 1.0 | 1.1 | 1.3 | 1.4 | 1.6 | 1.7 | 1.9 | 2.1 | 2.2 | 2.4 |
| 1800 | .2 | .3 | .5 | .7 | .8 | 1.0 | 1.2 | 1.3 | 1.5 | 1.7 | 1.8 | 2.0 | 2.2 | 2.4 | 2.5 |
| 1900 | .2 | .4 | .5 | .7 | .9 | 1.1 | 1.2 | 1.4 | 1.6 | 1.8 | 1.9 | 2.1 | 2.3 | 2.5 | 2.7 |
| 2000 | .2 | .4 | .6 | .7 | .9 | 1.1 | 1.3 | 1.5 | 1.7 | 1.9 | 2.1 | 2.2 | 2.4 | 2.6 | 2.8 |
| 2100 | .2 | .4 | .6 | .8 | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.5 | 2.7 | 2.9 |
| 2200 | .2 | .4 | .6 | .8 | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 |
| 2300 | .2 | .4 | .6 | .8 | 1.1 | 1.3 | 1.5 | 1.7 | 1.9 | 2.1 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 |
| 2400 | .2 | .4 | .7 | .9 | 1.1 | 1.3 | 1.6 | 1.8 | 2.0 | 2.2 | 2.5 | 2.7 | 2.9 | 3.1 | 3.4 |
| 2500 | .2 | .5 | .7 | .9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.1 | 2.3 | 2.6 | 2.8 | 3.0 | 3.3 | 3.5 |
| 2600 | .2 | .5 | .7 | 1.0 | 1.2 | 1.5 | 1.7 | 1.9 | 2.2 | 2.4 | 2.7 | 2.9 | 3.2 | 3.4 | 3.6 |
| 2700 | .3 | .5 | .8 | 1.0 | 1.3 | 1.5 | 1.8 | 2.0 | 2.3 | 2.5 | 2.8 | 3.0 | 3.3 | 3.5 | 3.8 |
| 2800 | .3 | .5 | .8 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.6 | 2.9 | 3.1 | 3.4 | 3.7 | 3.9 |
| 2900 | .3 | .5 | .8 | 1.1 | 1.4 | 1.6 | 1.9 | 2.2 | 2.4 | 2.7 | 3.0 | 3.2 | 3.5 | 3.8 | 4.1 |
| 3000 | .3 | .6 | .8 | 1.1 | 1.4 | 1.7 | 2.0 | 2.2 | 2.5 | 2.8 | 3.1 | 3.4 | 3.6 | 3.9 | 4.2 |

NOTE. Dissolve the dry bicarbonate of soda in four times its weight of water in a sprinkling can, and stir the corners of the vat where foam has accumulated.

6. The operator should make sure that the quantity of ice cream mix and the acidity test are correct, that the neutralizing solution has been properly mixed before removing the required amount, and that the neutralizer is properly diluted before adding it to the ice cream mix.

7. The pasteurizing process is completed.

**Pasteurization of the Mix.**—Pasteurization of an ice cream mix is necessary and, the authors believe, should be compulsory. The process is not expensive and certainly is a safeguard to such a highly nutritious food product. In addition, it actually aids in producing an ice cream of more uniform texture and flavor.

Various temperatures are used for pasteurization. Some manufacturers use a temperature so low that it fails to kill the majority of the pathogenic bacteria. This, of course, is a mistake. Ice cream mix, pasteurized at 145–150° F. and held at this temperature for thirty minutes, then homogenized at a temperature not below 140° F., gives excellent results. Heating to 155° F. does not injure the flavor, though a little longer time is required for the mix to regain the viscosity. Homogenization or viscolization should never be attempted above 150° F., for starchy flavor is likely to be evident in the finished product. For efficient methods of pasteurization, see chapter on Bacteria.

Care should be taken to see that all the ingredients except flavoring agents, fruits, nuts, and the like, are pasteurized. The viscosity destroyed by agitation during pasteurization is never regained. If it is assumed that at least a certain amount of basic viscosity is desirable, then every practical precaution should be taken to secure it. Proper agitation during pasteurization is one means of doing so. There should be just enough agitation to move the mix away from the heating surface fast enough to prevent burning, development of cooked or pasteurized flavors, and the coagulation of any albumin. Just what this speed should be depends upon the type of agitation, size of heating area, capacity of vat, and type of heating medium (steam or hot water). The following table[8] illustrates this point.

TABLE XXXIX

EFFECT OF AGITATION IN PASTEURIZER ON VISCOSITY

| Speed of Impeller, R.p.m. | Time Aged, Hours | Viscosity, Poises |
|---|---|---|
| 160 | 24 | 2.94 |
| 80 | 24 | 4.55 |

[8] Turnbow, G. D., and Milner, F. W., University of California, Unpublished work.

In these experiments, a glass-lined, jacketed, pasteurizing vat was used, and the pasteurizer filled. The table above is typical of the data on agitation.

Conditions that are correct for a full vat may be too severe for a small mix.

TABLE XL

Effect of Agitation upon Viscosity *

| Mix | Time Aged | Speed of Impeller, R.p.m. | Viscosity, Poises | Volume in Vat. |
|---|---|---|---|---|
| 19 | 24 | 160 | 1.22 | ⅓ full |
| 19 | 24 | 80 | 2.10 | Full |
| 21 | 24 | 160 | 2.55 | ⅓ full |
| 21 | 24 | 80 | 11.73 | Full |

* Turnbow, G. D., and Milner, F. W., University of California, Unpublished work.

This table demonstrates that at the end of twenty-four hours (the length of time a mix should be aged with the present methods) the vat one-third full had less than half the viscosity of the full vat, although it had been given twice as much agitation. Though some of these mixes were aged for longer periods of time, the relationship between them remained quite constant. It is possible, and undoubtedly true, that the excess agitation brought about greater dispersion of the fat, destroying the clusters; but this alone can hardly account for all the difference in the viscosity. Fixation of the serum solids by adsorption undoubtedly takes place to a lesser degree in the case of increased agitation. The mixes described in the last two tables were homogenized with a single-head homogenizer, which should allow for clustering of the globules. Regardless of the fact that approved methods may be used, pasteurization tends to destroy viscosity to some extent. The greater portion, however, is regained during aging. The following table by W. H. Martin [9] indicates the effect on viscosity of varying pasteurizing temperatures.

As would be expected, at temperatures above 145° F., and with a holding period longer than thirty minutes, the bacteria count was decreased. It appeared also that while the viscosity in the fresh mix, pasteurized at unusually high temperatures and held longer than the usual thirty minutes, was injured but little, the rate of developing viscosity during aging was retarded.

[9] Martin, W. H., Ice Cream Trade Journal, January, 1926, p. 55.

TABLE XLI

EFFECT OF PASTEURIZATION TEMPERATURES ON PROPERTIES OF THE MIX AND ICE CREAM

| Past. Temp., ° F. | Holding Time | Acid, Fresh, Per Cent | Acid, 48 Hours, Per Cent | Viscosity, Fresh | Viscosity, 48 Hours | Bacteria Count |
|---|---|---|---|---|---|---|
| 145 | 30 | 0.238 | 0.238 | 5.19 | 109.2 | 111,000 |
| 145 | 60 | 0.239 | 0.239 | 4.73 | 99.0 | |
| 145 | 120 | 0.242 | 0.242 | 4.26 | 84.4 | 60,275 |
| 153 | 20 | 0.237 | 0.243 | 6.33 | 95.5 | 49,275 |
| 153 | 60 | 0.242 | 0.242 | 4.73 | 83.0 | |
| 153 | 120 | 0.238 | 0.243 | 4.66 | 77.9 | 15,725 |
| 165 | 15 | 0.242 | 0.249 | 6.46 | 94.2 | 20,950 |
| 165 | 60 | 0.244 | 0.244 | 6.93 | 81.2 | |
| 165 | 120 | 0.244 | 0 250 | 5.46 | 75.3 | 14,512 |

After the mix has been properly pasteurized and the hot gelatin solution added and mixed, and the 5 or 6 c.c. of cheese color (if color is allowed) per 100 lbs. is added, the mix is ready to pass through the homogenizer or viscolizer, as the case may be.

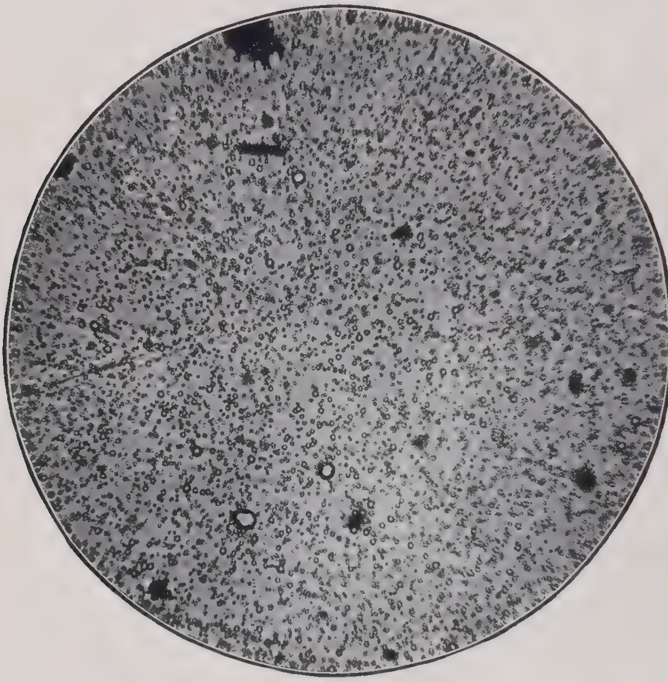
## HOMOGENIZATION

The homogenizer and the viscolizer, although somewhat different in mechanical construction, operate upon the same principle, namely, that of a triplex or three-cylinder pump. They are so constructed that the mix is forced through a very small, manually adjustable aperture. This process brings about no chemical changes. It is purely physical, being that of breaking up and increasing the surface area of the fat globules. Zsigmondy and Spear[10] really explained homogenization when they stated, "homogenization is fundamentally a process for mechanically increasing the degree of dispersion of fat."

The distinguishing difference between a homogenizer and viscolizer is the size of the aperture of the processing head through which the mix must pass. For this reason, 2000 lbs. pressure per square inch on the viscolizer is about equal to 3000 on the homogenizer. Operating at these pressures, the opening in the head of the homogenizer is 0.007 inch; in the viscolizing head, 0.003 inch. No one who produces large quantities

[10] Zsigmondy, R., and Spear, E. B., "Homogenization," in The Chemistry of Colloids, p. 265, 1917. John Wiley & Sons.

of ice cream expects to manufacture it from unhomogenized mix. Suffice it to say that homogenization or viscolization is essential for the manufacture of the ice cream demanded by the consumer. This process increases the viscosity of the mix, prevents churning of fat in the freezer, cuts down the time required for aging, and improves to a marked degree the texture and palatability of the finished product. In referring to the benefits of this process, it is understood that proper care is given the



*Courtesy M. Mortensen, Iowa State College*

Fig. 44.—Normal Dispersion of Fat Globules in Pasteurized Cream.

equipment. The suction line should be tight and should preferably be gravity-fed. The strainer should always be in the feed line, and particular attention should be paid to the valves to see that they are well ground. Considerable damage is often done if the valves are dropped into the seats; they should always be carefully set into place.

The homogenizing valve should be well seated (see Chapter XI). One should never be able to detect channels in the face of the valves. Valves in such a condition can affect the mix but little; and the larger portion of the benefits to be derived from homogenization are lost. Keeping the pistons well packed and occasionally changing the packing

will protect the homogenizer, prevent contamiation of the mix, and often save delay.

Homogenization increases viscosity by dividing the fat globules many times, thereby increasing the surface area exposed for the adsorption of the water and other colloids. Since there is less free serum, the viscosity is increased. Several investigators have shown that the butterfat globules form clusters after passing one stage in the homogenizing head, thereby further increasing the viscosity. It is doubtful whether the

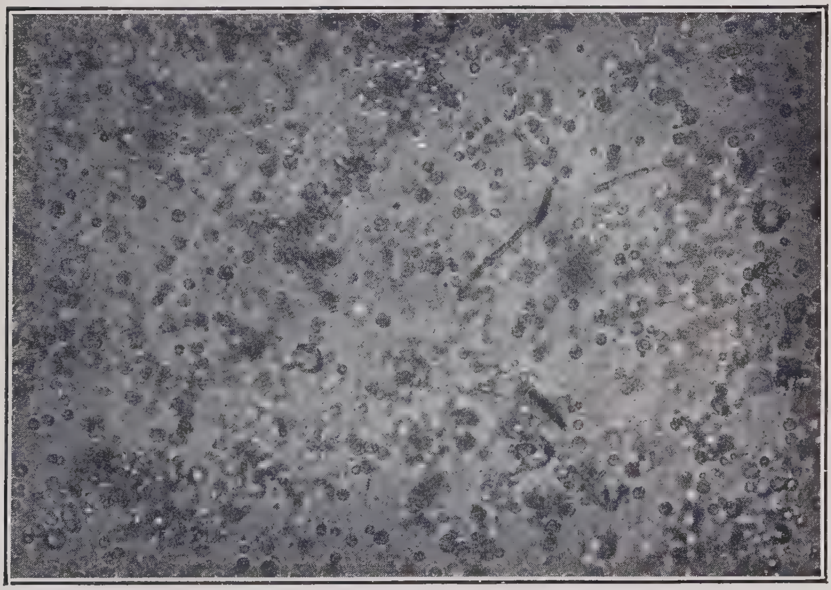


FIG. 45.—Pasteurized Mix Unhomogenized. Dil. 1 × 10.

viscosity obtained from these clusters is permanent or of any value, for they are easily destroyed by the dasher during the first period of the freezing process. The temperature at which the mix is homogenized influences the initial viscosity. The nearer the temperature of the mix is to the solidification temperature of the fat, the greater will be the number of the fat clusters, and the greater will be the initial viscosity of the homogenized mix. A mix homogenized at 100–110° F. will have practically twice the viscosity of a similar one homogenized at 145° F. Pressure has much to do with the viscosity. There is a relationship between acidity of the mix, homogenizing pressure, and the viscosity obtained.

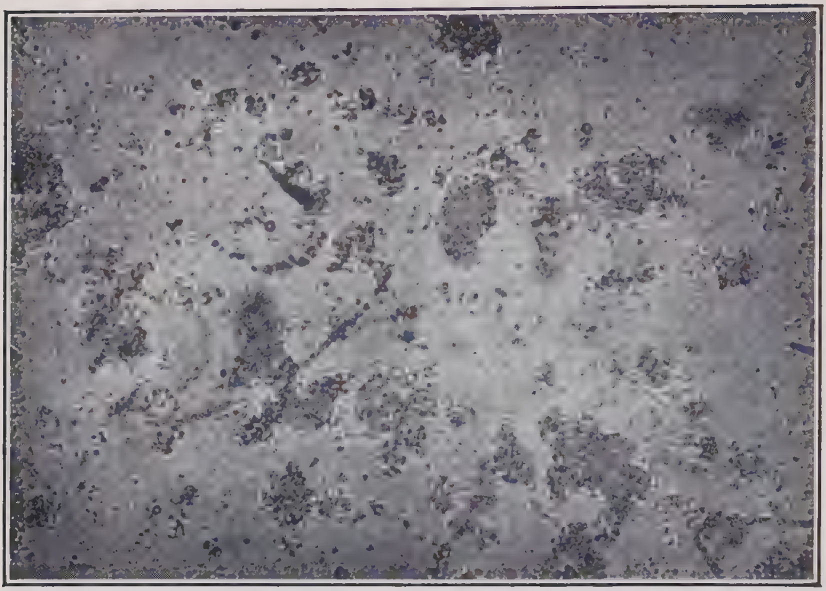


FIG. 46.—Pasteurized and Single-stage Homogenized Ice Cream Mix Showing Clustering of Fat Globules. Dil. 1 × 10. The Clusters are Largely Destroyed at the Beginning of the Agitation in the Freezer.

FIG. 47.—Pasteurized and Double-stage Homogenized Ice Cream Mix. Dil. 1 × 100.

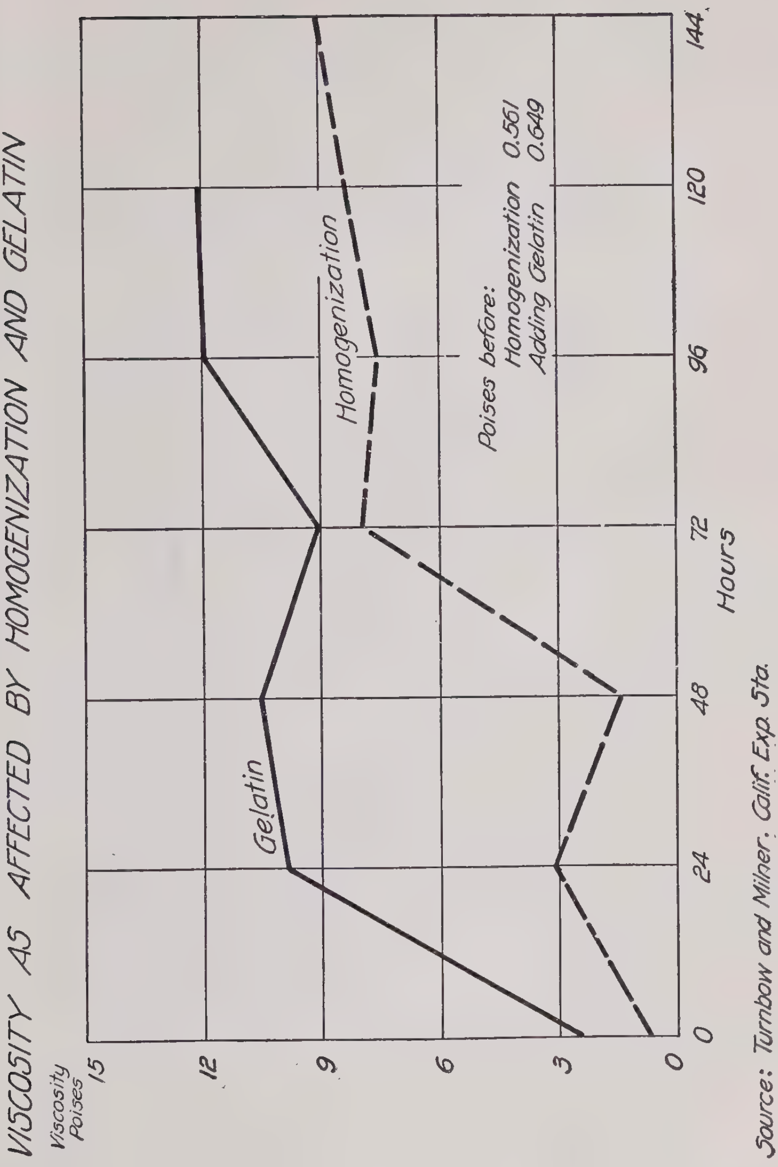

VISCOSITY AS AFFECTED BY HOMOGENIZATION AND GELATIN
Viscosity Poises
15
12
9
6
3
0
0
24
48
72
96
120
144
Hours
Gelatin
Homogenization
Poises before:
Homogenization 0.561
Adding Gelatin 0.649
Source: Turnbow and Milner. Calif. Exp. Sta.

FIG. 48.

**Relation of Acid to Homogenizing Pressure.**—Turnbow and Milner[11] show in the following table the effect of varying pressures upon viscosity. The data show that the higher the pressure, the acidity remaining constant, the greater the viscosity. If too much pressure is used in

TABLE XLII

EFFECT OF HOMOGENIZATION PRESSURE AND ACIDITY UPON VISCOSITY

| Mix | Acidity | Pressure, lbs. | | | | |
|---|---|---|---|---|---|---|
| | | 1500 poises | 2000 poises | 2500 poises | 3000 poises | 3500 poises |
| 48 | .260 | 10.92 | 11.00 | 11.96 | 15.60 | 16.64 |
| 47* | .227 | 2.41 | 3.51 | 4.68 | 6.786 | 7.09 |
| 43a | .256 | 14.04 | 17.68 | 20.80 | 23.80 | 26.52 |
| 49 | .230 | 7.32 | 10.02 | 11.25 | 12.45 | 13.02 |
| 50 | .246 | 9.62 | 14.00 | 15.00 | 21.61 | 27.24 |

* Reconstructed Mix.

conjunction with high acid in the mix, the viscosity will be so high that the mix can not run over an external tubular cooler, and will feather. A single-head homogenizer was used in obtaining the data in the above table. Based upon this and other similar work, as well as upon the work of other investigators, a table for practical use has been worked out.

TABLE XLIII

RELATION BETWEEN ACIDITY AND HOMOGENIZER PRESSURE (Single-stage)*

| Acidity of Mix | Homogenizing Pressure | Acidity of Mix | Homogenizing Pressure |
|---|---|---|---|
| 0.16 | 3500 | 0.24 | 2500 |
| 0.18 | 3250 | 0.26 | 2250 |
| 0.20 | 3000 | 0.28 | 2000 |
| 0.22 | 2750 | 0.30 | 1800 |

* Turnbow, G. D., and Milner, F. W., University of California, Unpublished work.

[11] Turnbow, G. D., and Milner, F. W., University of California Agr. Exp. Sta. Unpublished work.

If no changes are made in the composition or source of ingredients and if the method of processing is uniform, the viscosity of the mix from the homogenizer will be much more uniform. By using the above table, and varying the pressure to comply with the acidity of the mix to be homogenized, a fairly uniform viscosity can be obtained.

Some consideration has been given to the clustering of the fat globules immediately after homogenizing (single-stage). To summarize the work of Mortensen,[12] Dahle,[13] and Reid and Scism,[14] single-head homogenization allows the fat globules to recluster, with a resulting increase in viscosity.

Rehomogenizing and reviscolizing the mix, the second and even the third time, decreases the viscosity, probably as a result of a breaking up of the fat clusters. It is definitely known that in cases where mixes are homogenized by the two-stage homogenizer the viscosity is decreased. This is undoubtedly due to the breaking up of the clusters and their failure to recluster immediately after they have passed the second head. It is not known just why globules will cluster after leaving the first head but will not do so after leaving the second. The work at Missouri indicates that reprocessing improves the texture and that the dispersion of the fat is more important than viscosity. A single-head homogenizer operating at higher pressures tends to disperse the fat more completely than when operating at low pressure. There probably is also a greater degree of clustering at high pressures as well as a greater dispersion of fat, thereby producing more viscosity. Such viscosity (caused by clustering) is unstable and does not exist to any extent in the finished ice cream.

There is undoubtedly some clustering of the globules during aging, and, in the case of a mix homogenized the second and third time, in which the fat has been mostly dispersed, there is a tendency toward even greater clustering. This is borne out by work done at Missouri[15] in the conclusion reached that "an ice cream mix which has been reprocessed shows a greater increase of viscosity during aging than a mixture which has been processed but one time."

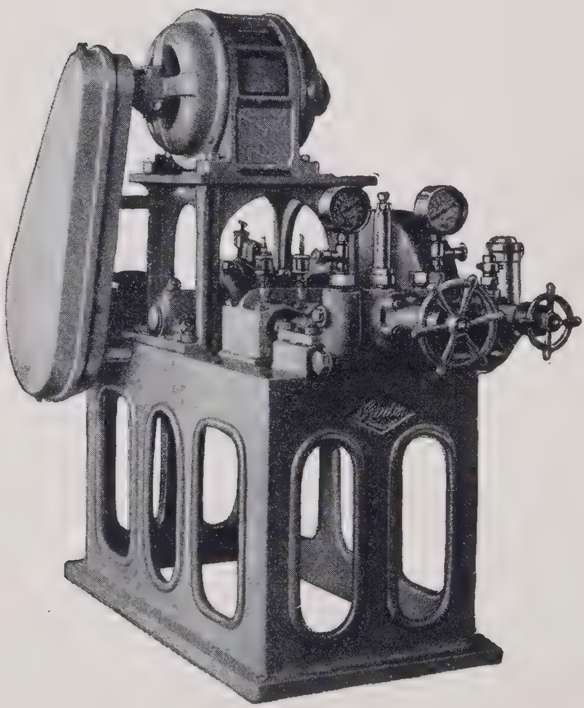
**Effect of Double Homogenization.**[16]—The following table indicates the variation in viscosity of the mix homogenized at varying pressures.

[12] Mortensen, M., Ice Cream Review, Nov., 1924, p. 146.
[13] Dahle, C. D., Ice Cream Trade Journal, Jan., 1926, p. 55.
[14] Reid, W. H. E., and Scism, S. F., Res. Bul. 82, Mo. Agr. Exp. Sta.
[15] Reid, W. H. E., and Scism, S. F., Res. Bul. 82, Mo. Agr. Exp. Sta.
[16] Martin, W. H., Ice Cream Trade Journal, January, 1926, p. 55.

TABLE XLIV

VISCOSITY OF ICE CREAM MIXES USING THE TWO-STAGE VALVE

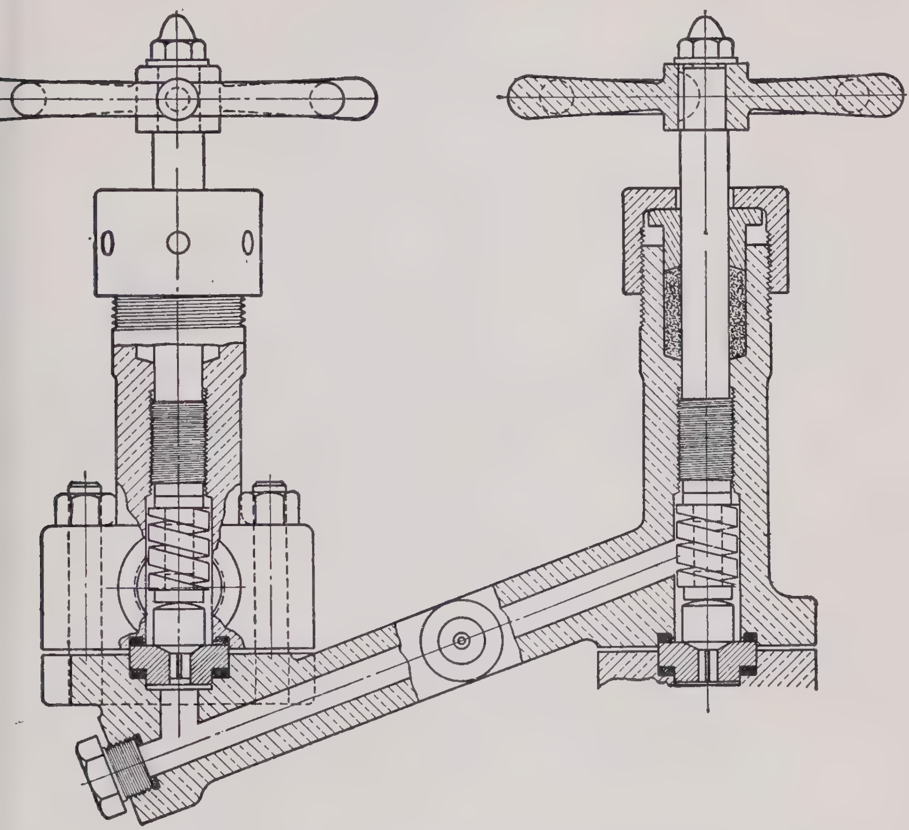
| Pressure Used | Viscosity, Fresh | Viscosity After 24 Hours | Viscosity After 48 Hours |
|---|---|---|---|
| None.......... | 5.901 | 26.28 | 28.62 |
| No. 1—None<br>No. 2—3000 | 53.66 | 88.28 | 105.04 |
| No. 1—4000<br>No. 2—3000 | 43.42 | 72.76 | 75.18 |
| No. 1—4000<br>No. 2—2000 | 28.06 | 45.53 | 56.99 |
| No. 1—3000<br>No. 2—1200 | 14.19 | 22.39 | 32.26 |



*Courtesy Manton–Gaulin Company*

FIG. 49.—Two-stage Homogenizer.

The table shows the rate of development of the viscosity during a period of forty-eight hours. It further shows what has already been mentioned, that most of the viscosity is reached at the end of the twenty-four-hour period, and although it continues to develop thereafter, the rate is much slower. It appears from this table that only a small

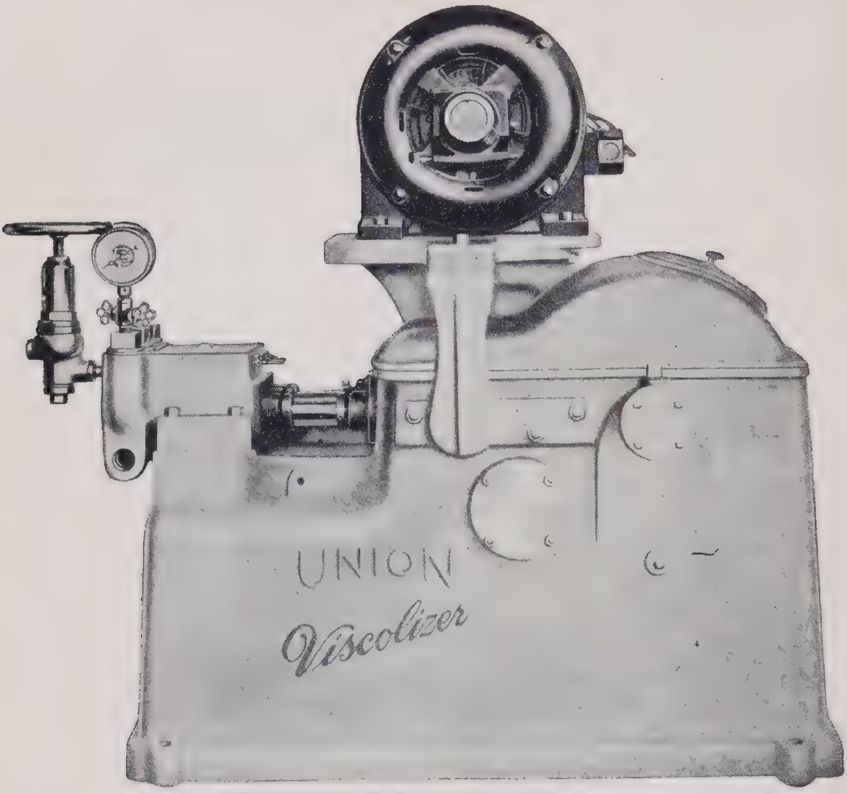


*Courtesy Manton–Gaulin Company*

Fig. 50.—Diagram of Two-stage Homogenizer Head.

amount of pressure on the second valve is required to disperse the clusters. If the first stage is used for homogenizing or dividing the fat globules, and only enough pressure (500 lbs.) used on the second stage to accomplish its intended purpose, the best results will be obtained. Too much viscosity is not desirable. It is possible that some other change during the aging period, besides the development of viscosity (as now determined), is responsible for many desirable characteristics

found in a smooth-textured ice cream. Homogenization, the proteins, and the fat all play important parts in occluding the water in such a manner that small crystals only (not large enough to be detected by the palate) are formed during the freezing and hardening of ice cream.




*Courtesy John W. Ladd Co.*

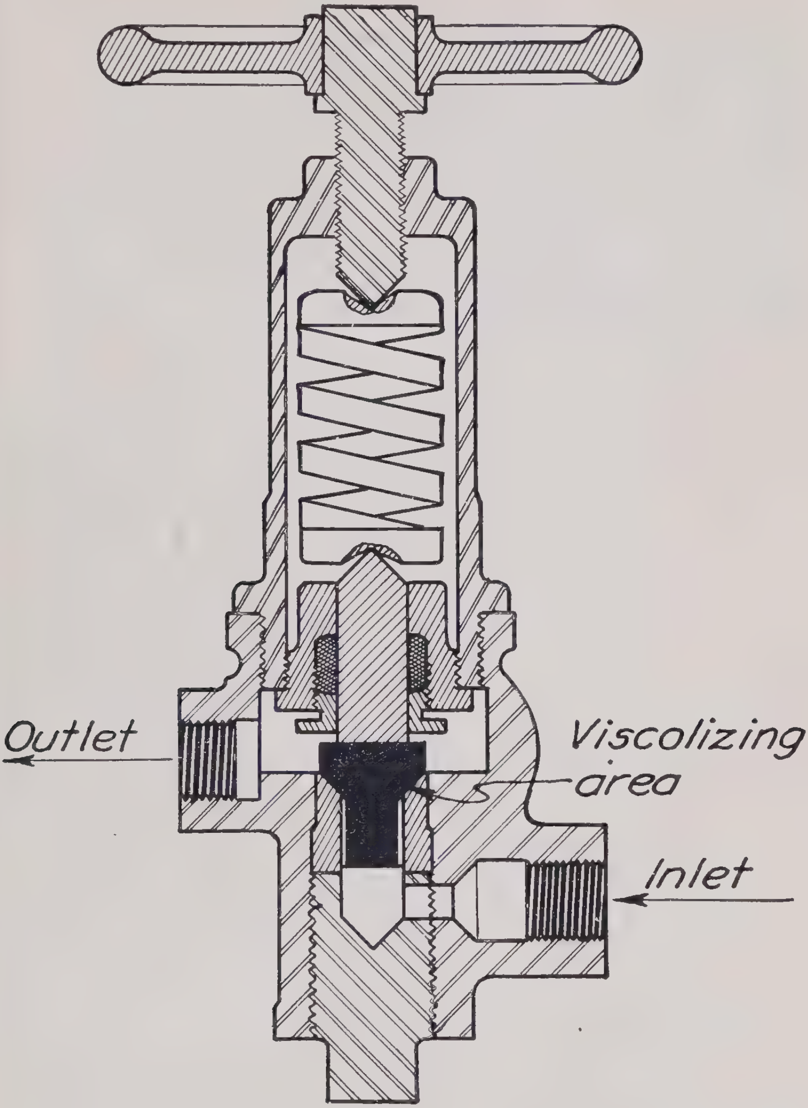
FIG. 51.—Viscolizer.

Homogenization affects the milk solids-not-fat only in the presence of butterfat.

**Cooling the Mix.**—Before the cooling operation, hot water (185° F.) should be pumped through the homogenizer and over the cooler to remove dust and dirt and any vegetative cells that may have developed since the equipment was cleaned.

The system for cooling the mix should be located as near the homogenizer as possible. The mix should be cooled quickly to the aging temperature. If it is allowed to stand at a warm temperature, the fat

may separate, even though it be finely dispersed. Especially is this true of mix homogenized once, or by single head. This has been

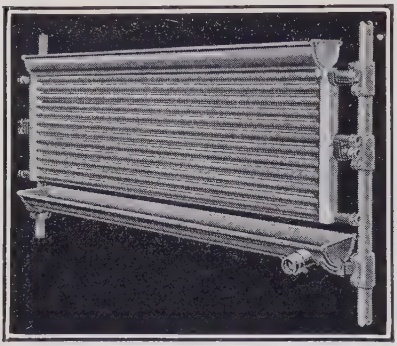



*Courtesy John W. Ladd Co.*

FIG. 52.—Diagram of Viscolizer Head.

explained as due to the clustering of the fat leaving the first stage of homogenization. The clusters then formed are broken up by the second

stage and do not recluster. This causes them to rise or separate much more slowly. A cooler of adequate capacity, preferably of the tubular type, equipped with water and brine connections, is recommended.



*Courtesy J. G. Cherry Co.*

Fig. 53.—Tubular Cooler.

The external type of cooler may be elevated, in order to allow the cooled mix to flow directly into the holding vat. The internal tubular type may be located on the floor, if a drain is provided at a convenient place near the homogenizer. The homogenizer will elevate the mix or force it through the cooler, as is desired.

The internal-tube type of cooler is easily sterilized. After it is washed, a steam hose or steam line may be connected. A temperature above 200° F. is quite easily obtained. No injury to the cooler results from the expansion and contraction, if it is of the expansion-head type.

An external tubular cooler is easy to wash but very difficult to sterilize.

The authors have obtained the usual yield from mix directly off the cooler. In this particular work, 100 per cent was desired and obtained. It required much longer (thirty-seven minutes) to complete the freezing process, and the resultant cream was open and weak and of an undesirable texture. This applies to a normal mix containing the usual percentages of fat, milk solids-not-fat, sugar, and gelatin. It is the general practice to age the mix for a period of time to develop what is termed viscosity. As has already been shown, viscosity can be obtained in many ways, but the method of measuring it remains the same. The amount of viscosity may appear to be the same, as it is now determined, although in reality it is not; i.e., even if the yield is obtained, the type of viscosity, plasticity, or elasticity may not be the same. In many cases, it is fundamentally different.

**Aging the Mix.**—As stated, holding the mix at the proper temperature for a period of time (twenty-four hours is usually long enough if it has been properly combined and processed; otherwise forty-eight hours may be required) is the most general practice. Turnbow and Milner,[17] as well as many other investigators, have shown that it is not unusual to obtain 300 per cent increase in viscosity during the first twenty-four hours, provided that the aging temperature is not about

[17] Turnbow, G. D., and Milner, F. W., Ice Cream Review, June, 1926, p. 136.

36° F. The second twenty-four-hour period only increased an average of 22+ per cent above the first. Identical mixes, aged at different temperatures for the same period of time, developed varying degrees of viscosity. In general, a mix aged at 32° F. (not to exceed 36° F.), is of better quality and has more viscosity than one aged at higher tempertures. This work included temperatures up to and including 50° F.

If the aging temperature is correct (32–36° F.), the freezing point is not affected nor is acid developed. (See Table, page 131.)

**Enzymes.**—In addition to developing viscosity by aging, some manufacturers use enzymes, supplied in the form of so-called improvers or mix standardizers. Still others use the enzyme solution in liquid form. Analysis of several improvers demonstrated that the active principle was rennet, pepsin, or a combination of the two. Some of the products that have been sold are of no value, so far as benefiting the ice cream is concerned. They simply form bulk and act as fillers. Such ingredients as gums (India and tragacanth), cane sugar, corn starch, and corn sugar are used in their make-up. If these materials are needed (and some of them are), they can be purchased under their own names at a much more reasonable figure.

Improvers furnish a convenient form of supplying the enzyme to the mix. Being in powder form, they will keep well and can be weighed out as needed. In the liquid form, which is the concentrated enzyme solution, a very small amount is required to accomplish the same thing. This form is also very convenient to use. Ice cream mix that must be frozen immediately after processing (due to shortage) will be benefited by the addition of the proper amount of enzyme. It will increase the viscosity, though in a different way from that obtained by aging. Enzymes do not prevent sandiness.

Since rennet is the active principle in most improvers, it is well to know more of its action. Some authorities claim that it is a mixture of two enzymes, rennin and pepsin; but, as a matter of fact, very few enzyme solutions contain a simple ferment. The products formed by the action of rennet or pepsin on the casein of milk to form calcium paracaseinate[18] are thought to be identical. Rennin action is undoubtedly chemical as well as colloidal. The forming of the calcium paracaseinate, due to the action of the enzyme, is not merely the precipitation of insoluble protein. It exerts a digestive action on the casein.[19] This action is what increases the viscosity of the ice cream mix and

[18] Van Slyke, L. L., and Bosworth, A. W., Tech. Bul. 31, New York Agri. Exp. Sta., 1913.

[19] Van Slyke, L. L., and Bosworth, A. W., Tech. Bul. 37, New York Agr. Exp. Sta., 1914.

makes a better product from fresh, unaged mix. If enough rennet or pepsin be added, the mix "sets," just as milk does in the manufacture of certain types of cheese. This, of course, is undesirable in ice cream, where only a viscous liquid is desired. The temperature of the mix at the time the improver is added will influence the amount required. If the mix is aged[20] at the recommended temperature, there is no increase in bacteria count, for improvers have no control over bacterial growth. If the enzyme solution is used, the amount will vary, depending upon length of time the mix is to be held, as well as the temperature and acidity of the mix. The amount varies from 10 c.c. to 40 c.c. per 100 gals. of mix.

**Freezing.**—Freezing is one of the important steps in the manufacture of ice cream. Considerable attention has been given this phase of the process, but it is doubtful whether the attention has been critical enough. The development of the freezer is interesting: first, the old hand-power tub with salt and ice was used; then power was applied to machines of the same type. Later the brine freezer was developed; and still later, the brine was replaced by ammonia, direct expansion being used. In the next few years some very important changes may be expected. From small capacities, the freezer has grown up to the 40, 50, 60, 80, 100, 120, and even 160-qt. freezers which are now in use. By far the greatest number of freezers, however, are of 40-qt. capacity, and most of these are of the horizontal type. The vertical machine is not so popular as it was a few years ago.

Very few experimental data are available as to the most economical capacity of freezer. Present indications are that the 100-qt. capacity machine may be operated more economically than sizes above or below. Of course, this statement applies to plants of sufficient volume to justify so large a freezer. The freezing process, while it has the appearance of a simple operation, really makes a great change in the product, most of which is desirable. The receiving vat of the freezer should always be thoroughly rinsed out with hot water to remove the vegetative cells and any other bacteria that may have developed since the last freezing.

**Care of the Freezer.**—Some ice cream manufacturers take advantage of the low temperatures at which ice cream is frozen. At the close of the freezing operations for the day, the freezer is often left unsterilized or is perhaps only rinsed out with water and considered ready for the next day. Rinsing only warms the freezer more quickly, thereby causing the growth of bacteria to commence earlier. Health departments will not knowingly tolerate it, and managers should not permit it. Bacterial standards are sure to be made more rigid, and inspection more critical,

[20] Parfitt, E. H., Ice Cream Trade Journal, Nov., 1923, p. 79.

if such practices are allowed. It is not a big job to open the head of the freezer, pull the dasher, and thoroughly clean it after the day's work. In the case of larger machines, a "dolly" or "cradle" to handle the dasher can be constructed easily and cheaply. Sterilizing the freezer with steam after it is put together again, and rinsing with hot water just before beginning of the day's freezing operations, will materially aid in preventing bacterial contamination. (See Bacteria in Ice Cream.) Naturally, a better-flavored, cleaner, more sanitary, and safer food is the result. The importance of this article of food justifies every precaution.

The freezing point of a mix varies with the composition, as has already been pointed out. This being the case, only general instructions regarding freezing, and a summary of the effect of the various operations upon the finished product, can be given here.

The temperature of the brine, the pressure of the brine, the difference in temperature of the incoming and outgoing brine, the speed of the dasher, the type of dasher, the rated capacity of the freezer, the firmness of the cream desired, the yield desired, the time required to empty, and the degree to which it is emptied must be synchronized. This, obviously, is not an easy thing to do, and even when one has done it, making use of all information, the results are not perfect. A uniformly perfect texture and the accurate control of weight per gallon are not being accomplished. It must be admitted that these, as well as other factors, should be controlled and, no doubt, will eventually be controlled.

It has already been stated that a mix should be aged at 32° F., or not more than 36° F. If the mix is properly homogenized and cooled, no separation takes place. It has been shown that there is an increase in viscosity during aging. Assuming that this is desirable, it should be retained as far as possible.

**Function of the Freezer.**—The freezer has been constructed for the purpose of more economical handling and for the production of better ice cream. To produce the latter, it is necessary that the solids in the mix, when frozen, be not too close together. The dasher is so constructed, and revolves in such a way that a gas, usually air, may be incorporated into the cream during the freezing process to separate the solids and thereby eliminate a soggy or heavy product. The dasher is divided into two main sections. Theoretically, it accomplishes three functions. First, it aids in the rapid transmission of heat, thereby preventing the freezing of ice on the inner chamber wall. This is accomplished by the scraper blades, which should be properly fitted to the inner chamber wall and kept sharp, with no burr or feather edge on the back of the blade. The second function is the incorporation of air in a

finely divided state. This is very important, since the quality of the finished product, as well as the financial return for it, depends upon the control of this operation. This is theoretically accomplished largely by the beater. The accuracy of this statement depends, however, on the construction of the beater.

The third operation, the unloading of the freezer, is accomplished by the unloading wings, or arms. These are built in the dasher in spiral form, or in the form of small blades, which work the semi-frozen ice cream toward the front of the freezer.

The two divisions of the freezer dasher may be described as the scrapers and unloading device, or outside mechanism, which operate together and in the same direction, usually clockwise; and the beater, or internal mechanism, which operates in the opposite direction. Both the external and the internal mechanisms on the market to-day operate simultaneously at the same speed. The desirability of this mechanical hook-up in unison is questioned.

**Function of Scraper and Beater.**—The original construction of the dasher is very similar in all freezers, and few basic changes in the principle of operation have been made. The variation in weight per gallon of each gallon drawn from a run has been shown. To study the true function of each division or section of the freezer, the beater was disengaged and operated independently, by a separate motor. The following table indicates what can be done in obtaining a uniform weight per gallon for each can drawn from a run:

TABLE XLV

Effect on Density Variation on Consecutive Cans as Drawn from Freezer While Beater Was Off During the Drawing Process. Data Taken from 24 Freezers

(Data in Pounds per Gallon)

| | First and Second Can | First and Third Can | First and Fourth Can | First and Fifth Can | First and Sixth Can |
|---|---|---|---|---|---|
| Average variation | 0.029 | 0.059 | 0.124 | 0.116 | 0.075 |
| Maximum variation | +0.10 | −0.16 | +0.23 | +0.20 | −0.10 |
| Minimum variation | ±0.00 | +0.02 | ±0.00 | ±0.00 | +0.05 |
| Maximum positive variation | +0.10 | +0.15 | +0.23 | +0.20 | +0.05 |
| Maximum negative variation | −0.07 | −0.10 | −0.20 | −0.15 | −0.10 |

This table represents 24 complete runs. The fundamental difference in operation that proved to be the deciding influence in control of yield

was the stopping of the beater during the unloading process. As soon as the drawing or unloading process begins, there is a rapid increase in air and consequently a decrease in weight of the second can drawn. By stopping the beater and minimizing the whipping effect of the outside mechanism of the dasher, very little air is incorporated. The third can drawn generally increases in weight. This can be explained by observing the slapping action of the beater after the second can has been drawn and the blades have become exposed. This is not the case when only one can has been drawn. Just how closely weight can be controlled by using this separated beater construction will depend upon the construction of the remaining parts of the dasher, and upon the r.p.m. When the beater is off, the time required to unload is not affected. The beater apparently does not assist then in the unloading of the cream. The work of Turnbow and Neilson[21] shows that it does not incorporate much of the air but acts rather as an emulsifier by dividing the air cell. The beater also aids in the transfer of heat during the freezing process. This is demonstrated in Table XLVI, representing tests in which the beater was entirely removed from the freezer, and the cream frozen. Then the beater was replaced and the freezing continued.

TABLE XLVI *

INFLUENCE OF BEATER ON TIME TO FREEZE AND WHIP

| Mix Number | Amount of Mix, Pounds | Temperature of Mix, ° F. | R.p.m. of Beater | R.p.m. of Scrapers | Temperature of Brine (Incoming), ° F. | Time Required to Freeze | Yield † When Brine Was Turned Off | Time Required to Whip | Total Time to Freeze and Whip | Beater Removed from Freezer |
|---|---|---|---|---|---|---|---|---|---|---|
| 11–A | 45 | 41 | Out | 211 | +2 | 10′46″ | 86 | 2′2″ | 12′48″ | Yes |
| B | 45 | 41 | Out | 211 | +2 | 10′51″ | 94 | 1′14″ | 12′5″ | Yes |
| C | 45 | 41 | Out | 211 | +2 | 10′35″ | 89 | 1′58″ | 12′33″ | Yes |
| D | 45 | 41 | Out | 211 | +2 | 10′54″ | 88 | 1′33″ | 12′27″ | Yes |
| E | 45 | 41 | 215 | 211 | 0 | 8′11″ | 90 | 2′29″ | 11′10″ | No |
| F | 45 | 41 | 215 | 211 | +1 | 8′10″ | 91 | 2′25″ | 10′35″ | No |
| G | 45 | 41 | 215 | 211 | +1 | 8′11″ | 82 | 2′23″ | 10′34″ | No |

* Turnbow, G. D. and Nielson, K. W., University of California. Unpublished data.
† Determined by Mojonnier overrun tester.

[21] Turnbow, G. D., and Neilson, K. W., University of California, Agr. Exp. Sta. Unpublished data.

It will be noted that the brine temperature changed a little, while the beater was being put in, but the slight change could not account for the entire change in time required to freeze and whip. The part played by the beater is not as great as might be expected. The yield at the time the brine was turned off varies 12 per cent. This percentage of variation can be entirely attributed to the method of determining the yield, and not to any effect the beater may or may not have had.

It is just as necessary in ice cream as in bread that a certain lightness or separation of the solids prevail. Too much, however, in either case is undesirable and injures the product. The amount of air or gas to be incorporated depends upon the percentage of total solids in the product. This increase in volume, due to the separating of the solids, is referred to as yield. The amount of yield obtained from a given volume of mix naturally affects the weight per given volume of the finished product. Weight control will be discussed more in detail later in this chapter.

The brine should be turned on long enough thoroughly to chill the freezing chamber before any mix is drawn into the freezer. The dasher should be operating before the brine is turned on, particularly in horizontal freezers, for there may be a small amount of water in the bottom of the freezer, which, as ice, can injure the scrapers. As soon as the mix is let down, there is a marked drop in the viscosity. Some investigators claim it is regained; in work of the authors, however, this viscosity was never regained. The decrease in viscosity is probably due to two changes: one, a destruction of the colloidal structure, which may be partially regained, and the other, a destruction of the fat clusters, which is never regained. It is true that the viscosity increases in the freezer, but this increase is not the regaining of the original or same kind of viscosity; it is a new viscosity brought about by the effect of temperature on the solids in true solution and the strengthening of the remaining colloidal structure. According to Bogue,[22] gelatin exists in the form of short threads, which at low temperatures increase in length, forming a complete net-like structure. As the gelatin threads lengthen, they absorb water, assuming a swollen condition, which accounts in part for the increase in viscosity. The proper synchronizing of all the factors involved will aid in securing the retention of the maximum amount of viscosity in the finished cream. It is here that viscosity should do the most good.

**Speed of the Dasher.**—The speed of the dasher varies with conditions in the plant and with the make of the freezer. The dasher speeds of commercial freezers usually vary from 165 to 240 r.p.m. A few manu-

[22] Bogue, Chemistry and Technology of Gelatin and Glue, p. 146. McGraw-Hill Book Co., 1922.

facturers have lowered the speeds of their machines to 140 and some to 125 r.p.m. Sufficient yield can be obtained in a properly prepared mix at an r.p.m. as low as 125, especially since the gums, formerly used quite extensively, have been eliminated. Gums—especially the poorer grades—limit the incorporation of air.

The following table[23] shows the effect of the dasher on the viscosity of mixes aged at four different temperatures. It will be noted that most of the decrease in viscosity came during the first thirty seconds of the freezing period, and that from this time on it gradually decreased.

TABLE XLVII

EFFECT OF TEMPERATURE AND AGITATION UPON VISCOSITY

| Temp. Aged | Viscosity (Poises) | | | | | | | | 30 Wire |
|---|---|---|---|---|---|---|---|---|---|
| | Init. | 30″ | 1′0″ | 1′30″ | 2′0″ | 2′30″ | 3′0″ | 7′0″ | 9′0″ |
| 46 | 12.48 | 4.68 | 4.16 | 3.90 | 3.64 | 3.12 | 2.86 | 1.83 | 1.30 |
| 41 | ....... | 3.64 | 3.60 | 2.60 | 2.60 | 2.60 | 2.70 | 1.56 | 1.56 |
| 34 | ....... | 5.56 | 4.52 | 4.00 | 3.64 | 3.74 | 3.28 | ....... | 2.60 |
| 32 | 16.64 | 7.80 | 9.36 | 9.36 | 7.80 | 8.32 | 10.40 | 4.94 | 4.94 |

The speed of the dasher in all four cases was 140 r.p.m. The second and fourth mixes were aged forty-eight hours; the first and third, twenty-four hours. If the experimental error could be eliminated no doubt the viscosity would vary but slightly. The acidity of the mix when made was 0.210 of 1 per cent.

The speed of the dasher affects the viscosity, as shown in the following table·

TABLE XLVIII

EFFECT OF SPEED OF DASHER UPON APPARENT VISCOSITY

| Initial Viscosity | Speed of Dasher | Viscosity at Time Brine Was Turned Off |
|---|---|---|
| 18.30 | 140 | 12.17 |
| 16.64 | 71 | 12.30 |
| 16.64 | 106 | 11.57 |

[23] Turnbow, G. D., and Milner, F. W., Ice Cream Review, June, 1926, p. 136.

It is noted that the r.p.m. of the dasher varied from 71 to 140; also, that two mixes are identical. The slight variation in the viscosity may be attributed to experimental error.

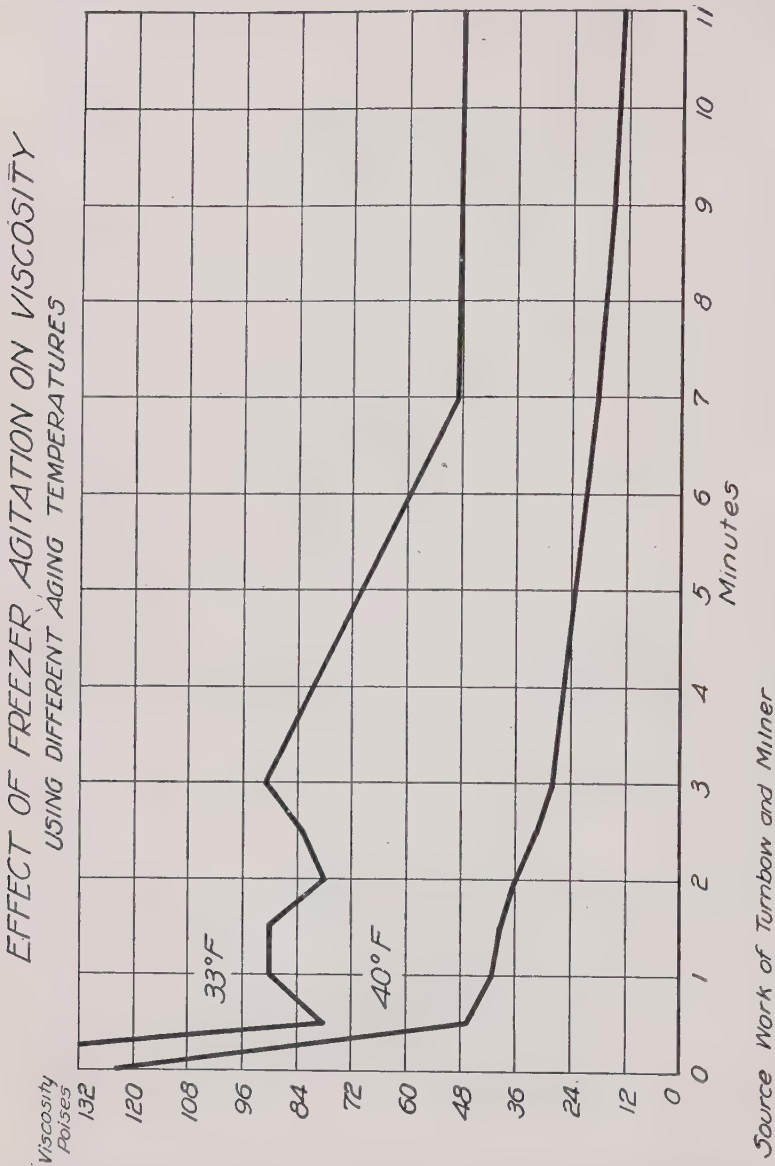



FIG. 54.—The Apparent Viscosity is Largely Destroyed During the First Few Minutes of Agitation in the Freezer. The Viscosity that Remains is Known as "Basic Viscosity."

The speed of the dasher during the freezing process affects the total time required to complete the process. The following table illustrates

the effect of varying speeds and represents the average of over 1000 gals. of ice cream.

TABLE XLIX

RELATION OF THE SPEED OF THE SCRAPER TO THE TIME OF THE ENTIRE FREEZING PROCESS

| Speed of Scraper, R.p.m. | Speed of Beater, R.p.m. | Brine Range | Time to Freeze | Time to Whip | Total Time |
|---|---|---|---|---|---|
| 70 | 150 | −2 | 12′07″ | 16′43″ | 28′50″ |
| 106 | 150 | −2 | 7′21″ | 11′24″ | 18′45″ |
| 140 | 150 | −2 | 7′0″ | 5′18″ | 12′18″ |
| 211 | 150 | −1 | 6′23″ | 4′29″ | 10′52″ |

**Brine Temperature.**—Decreased brine pressure resulting in decreased volume is often the cause of the extended time required to freeze. An adequate supply of cold brine (0° F.) is needed, and the proper volume must be delivered to the freezers. Often, in a battery of freezers, those nearest the brine inlet get the greater supply. Freezers should be equipped with two thermometers, one on the inlet and one on the discharge. Then, the brine flow should be so regulated that the incoming and outgoing brine have the same temperature spread on each freezer. This alone will do much toward producing uniform ice cream. It must be kept in mind also that not all machines freeze alike. This variation may be due to some mechanical defect, scale, speed of the dasher, the condition of the bearings, volume of brine, brine pressure, or any number of factors influencing the operation of the freezer

**Scraper Blades.**—The scraper blades should be kept in contact with the entire surface of the inside wall. When this is not done, slow freezing, low yield, or grainy ice cream may result. The effect of poorly operated scraping blades is shown in the following table.

The average time required for the processing of Batch 9 was 25 minutes 6 seconds, while for 15A it was 20 minutes 48½ seconds. The difference here is due to the fact that in one case the blades were operating as was intended, while in the other they were in such poor condition (dull and burred) that the cream was freezing to the walls, forming an insulation which prevented the rapid transfusion of heat, as well as producing coarse icy ice cream. On account of the low brine pressure, too great a length of time was required, in both cases, for freezing. A variation of not more than 3–5° F. between incoming and outgoing brine is the maximum.

TABLE L *

EFFECT OF CONDITION OF SCRAPERS ON TIME TO FREEZE

| Batch | Speed of Dasher | | Time | | | Brine Pressure |
|---|---|---|---|---|---|---|
| | Freezing | Whipping | Freezing | Whipping | Total | |
| 9 (Scrapers in poor condition) | 140 | 140 | 14′40″ | 9′30″ | 28′10″ | 15 |
| | 140 | 140 | 15′00″ | 8′40″ | 23′40″ | |
| | 140 | 140 | 14′00″ | 12′55″ | 26′55″ | |
| | 140 | 140 | 11′40″ | 14′05″ | 25′45″ | |
| | 140 | 140 | 12′45″ | 12′15″ | 25′00″ | |
| Average.... | ........ | ........ | 13′45″ | 11′29″ | 25′14″ | |
| 15–A (Scrapers in good condition) | 140 | 140 | 9′30″ | 10′00″ | 19′30″ | 15 |
| | 140 | 140 | 9′40″ | 11′00″ | 21′40″ | |
| | 140 | 140 | 9′20″ | 9′05″ | 18′25″ | |
| | 140 | 140 | 10′15″ | 11′15″ | 21′00″ | |
| | 140 | 140 | 10′45″ | 11′15″ | 22′00″ | |
| | 140 | 140 | 10′40″ | 11′20″ | 22′00″ | |
| Average.... | ........ | ........ | 10′01″ | 10′39″ | 20′40″ | |

* Turnbow, G. D., and Milner, F. W., University of California Exp. Sta. Unpublished work.

The mix should be frozen stiff enough to allow the incorporation of sufficient air and the separation of the solids, and to ribbon or pile slightly when drawn into the container. Freezing the mix too stiff, before the brine or freezing medium is turned off, may cause grainy ice cream, slow emptying of the freezer, and greater variation in the weight. Though a cream may contain the correct amount of air, part of the mix may have been congealed and the air may necessarily have been incorporated into the remainder. This causes a variance in the uniformity, larger ice crystals, and lack of smoothness. If the brine is turned off too soon, the desired amount of air sometimes cannot be incorporated during the whipping period, or, in case its incorporation is possible, the cream is delivered to the can too soft. With such a condition ice crystals form, expecially around the outside. Furthermore, the air cells migrate upward, leaving heavier cream in the bottom of the can and lighter in the top, though the net weight per gallon of the ice cream may be all that is desired.

The air cells of a cream that has been properly frozen should remain in position without change. This is illustrated in Table LII (the weight of ice cream at varying depths). The variations here are due to experi-

mental error and to the occasional folding in of an air pocket in the filling of the can. If the cream is drawn too hard, more air pockets are usually entrapped. This is not a serious source of variation in weight, however.

**Freezer Load.**—The freezer load, that is, the amount of mix frozen with each run, should be established and maintained. There are various batch measures and weighers on the market, most of which have some objectionable features that have prevented their universal acceptance. Many manufacturers have placed overflow pipes in the sides of the receiving hopper. When the mix is let into the receiving hopper, any excess over the desired volume overflows to a separate container. As this fills, it is poured into the receiving hopper. A counter is sometimes placed in the inlet valve or discharge gate of the freezer to keep track of the runs. All of this, of course, can be defeated if the coöperation of the freezer man is not obtained. Various other methods are in use for checking and are discussed later.

If the same load or amount of mix is placed in the freezer each time, frozen to the same degree of stiffness before the brine is turned off, and whipped to the desired end point (see Yield Control), and if the freezer is emptied to the same degree each time, a uniform ice cream of fairly constant weight per gallon can be produced. The points mentioned here are very important, though some of them have heretofore been given little if any consideration by manufacturers.

**Benkendorf Overrun Tester.**—Determination of weight by a sample has been suggested. Some years ago Benkendorf devised a method for determining yield. It consisted principally of a brass cylinder of known capacity for obtaining the sample of ice cream. The sample was melted down with a known volume of hot water, the foam was destroyed by ether, and the difference in the space occupied by the frozen ice cream and the melted ice cream was the basis for calculating the yield. This brass cylinder used in obtaining the data in the following table was standardized accurately as to capacity, and a large number of samples of frozen ice cream were taken. The net weight of the sample obtained was determined, and from this the weight per gallon was calculated. The inaccuracy of such a method can be easily seen from table LI.

This table deals with ice cream of fairly high percentage of yield and with equally high percentage of solids. In table LII is shown the average variation in the weight at varying depths, as determined with the Benkendorf sampler.

The ice cream is a little heavier at the bottom than at the top, though the extreme variation of these averages is slightly less than 0.1 lb. per gallon. Partly filled cans or cans that have been filled from two or more runs always show greater variation in weight. In fact, their weights are

TABLE LI

COMPARISON OF ACTUAL WEIGHT WITH CALCULATED WEIGHT BY BENKENDORF SAMPLER

| Weight Sampler Plus Ice Cream, Grams | Tare Weight Sampler, Grams | Net Weight Ice Cream, Grams | Weight per Gallon (Calculated), Pounds | Weight per Gallon (Actual), Pounds | Deviation from Actual Weight, Pounds |
|---|---|---|---|---|---|
| 81.5 | 58.7 | 22.8 | 3.92 | 3.84 | +.08 |
| 82.0 | 58.7 | 23.3 | 3.99 | 3.84 | +.15 |
| 80.3 | 58.7 | 21.6 | 3.70 | 4.22 | −.52 |
| 80.4 | 58.7 | 21.7 | 3.71 | 4.22 | −.51 |
| 81.5 | 58.7 | 22.8 | 3.92 | 3.84 | +.08 |
| 81.2 | 58.7 | 22.5 | 3.86 | 4.03 | −.17 |
| 80.6 | 58.7 | 21.9 | 3.75 | 4.03 | −.28 |
| 80.9 | 58.7 | 22.2 | 3.80 | 4.03 | −.23 |
| 81.0 | 58.7 | 22.3 | 3.83 | 4.03 | −.20 |
| 81.25 | 58.7 | 22.5 | 3.86 | 4.03 | −.27 |
| 81.3 | 58.7 | 22.6 | 3.88 | 4.03 | −.25 |
| 81.0 | 58.7 | 22.3 | 3.83 | 4.03 | −.20 |
| 81.6 | 58.7 | 22.9 | 3.93 | 4.13 | −.20 |
| 80.5 | 58.7 | 21 8 | 3.73 | 3.92 | −.19 |
| 81.6 | 58.7 | 22.9 | 3 93 | 4.22 | −.29 |
| 81.0 | 58.7 | 22.3 | 3.83 | 4.22 | −.39 |

TABLE LII

AVERAGE WEIGHT PER GALLON AT DIFFERENT DEPTHS

| Depth | Average Weight per Gallon (Benkendorf) | Actual Weight per Gallon |
|---|---|---|
| 1 (Top) | 3.853 | 3.925 |
| 2 | 3.871 | 3.925 |
| 3 | 3.894 | 3.925 |
| 4 | 3.868 | 3.925 |
| 5 | 3.910 | 3.925 |
| 6 (Bottom) | 3.928 | 3.925 |

very hard to control. It is very desirable to be able to control the yield of each run so that a certain number of full cans and no part ones may be drawn. This will aid materially in producing uniform weight.

Glass cylinders were prepared by grinding one end to a very sharp edge and calibrating the volume. Samples of hard ice cream were obtained for weighing. Table LIII shows a summary of this work.

TABLE LIII *

Determination of the Weight per Gallon by Glass Sampling Tube

| Volume Sample, c.c. | Weight Tube Plus Sample Ice Cream, Grams | Tare Weight Tube, Grams | Net Weight Ice Cream, Grams | Calculated Weight per Gallon, Pounds |
|---|---|---|---|---|
| 50 | 162 | 134 | 28.0 | 4.8 |
| 50 | 160. | 134 | 26.0 | 4.36 |
| 50 | 160.6 | 134 | 26.6 | 4.39 |
| 50 | 159.9 | 134 | 25.9 | 4.34 |
| 50 | 159.4 | 134 | 25.4 | 4.20 |
| 50 | 159.5 | 134 | 25.4 | 4.20 |
| 50. | 159.5 | 134 | 25.5 | 4.29 |
| 50 | 162.9 | 134 | 28.9 | 4.85 |
| 50 | 160.2 | 134 | 26.2 | 4.38 |
| 50 | 159.8 | 134 | 25.8 | 4.31 |
| 50 | 161.3 | 134 | 27.3 | 4.56 |
| 50 | 161.5 | 134 | 27.5 | 4.60 |
| 50 | 160.4 | 134 | 26.4 | 4.41 |

* Turnbow, G. D., and Milner, F. W., University of California Exp. Sta. Unpublished data.

This method is not as accurate as the Benkendorf cylinder already described. In no case can too much accuracy be maintained in taking these small aliquot samples, as a slight error in technique makes a large error in the calculated weight.

**Accuracy of Cans.**—In order to determine if ice cream cans, both when sold and after use, were accurate enough to be used to determine the weight of ice cream per gallon, Turnbow and Milner[24] carried out the following work:

The cans secured for standardization were new, and were obtained on the open market. They were of various standard sizes (1's, 2's, 3's, and 5's) and represented most of the standard brands.

No can, regardless of size or brand, was below standard. The cans were standardized with the weight of an equal volume of water at a temperature of 4° C.

[24] Turnbow, G. D., and Milner, F. W., University of California Agr. Exp. Sta., Unpublished work.

TABLE LIV A

CALIBRATION OF NEW CANS

| Can Number | Assumed Volume, Gallons | Gross Weight | Tare Weight | Net Weight | Actual Volume, Gallons |
|---|---|---|---|---|---|
| 1 | 5 | 53.2 | 11.0 | 42.2 | 5.06 |
| 2 | 3 | 33.61 | 8.75 | 24.9 | 3.0 |
| 3 | 2 | 21.95 | 5.2 | 16.75 | 2.01 |
| 4 | 5 | 53.75 | 11.32 | 42.43 | 5.11 |
| 5 | 3 | 32.45 | 7.3 | 25.15 | 3.03 |
| 6 | 2 | 21.7 | 4.95 | 16.75 | 2.01 |
| 7 | 1 | 11.95 | 3.45 | 8.5 | 1.002 |
| 8 | 5 | 53.29 | 11.95 | 42.33 | 5.1 |
| 9 | 3 | 32.09 | 7.7 | 25.2 | 3.03 |
| 10 | 2 | 21.7 | 5.1 | 16.6 | 2.0 |
| 11 | 1 | 11.95 | 3.52 | 8.43 | 1.01 |
| 12 | 5 | 52.0 | 10.3 | 41.7 | 5.0 |
| 13 | 3 | 32.5 | 7.6 | 24.9 | 3.0 |
| 14 | 2 | 21.68 | 4.95 | 16.73 | 2.04 |
| 15 | 1 | 11.55 | 3.2 | 8.35 | 1.0 |
| 16 | 5 | 53.75 | 12.0 | 41.75 | 5.01 |
| 17 | 3 | 32.6 | 7.6 | 25.0 | 3.01 |
| 18 | 2 | 21.2 | 4.5 | 16.7 | 2.01 |
| 19 | 1 | 11.35 | 2.9 | 8.45 | 1.01 |

Old cans in use in an ice cream plant were also standardized in the same way. These represented different makes and capacities. No selections were made, the cans being picked at random. A few of the results, to illustrate, are given in the following table.

TABLE LIV B

CALIBRATION OF OLD CANS

| Can Number | Assumed Volume, Gallons | Gross Weight | Tare Weight | Net Weight | Actual Volume, Gallons |
|---|---|---|---|---|---|
| 1 | 1 | 11.3 | 3.0 | 8.3 | .995 |
| 2 | 2 | 21.05 | 4.5 | 16.55 | 1.987 |
| 3 | 3 | 31.2 | 6.27 | 24.93 | 2.992 |
| 4 | 5 | 51.9 | 10.25 | 41.63 | 4.996 |
| 5 | 1 | 11.4 | 3.10 | 8.3 | .995 |
| 6 | 2 | 21.3 | 4.84 | 16.46 | 1.985 |
| 7 | 3 | 32.8 | 7.8 | 25.0 | 2.988 |
| 8 | 5 | 52.15 | 10.75 | 41.4 | 4.995 |

In practically all cases, the old used cans were slightly under capacity but not sufficiently so to cause any noticeable difference. Cans should be filled full, scraped to insure uniform gallonage, and then hardened. During the hardening process, a slight increase in volume takes place; this will more than offset the shortage in volume in old cans.

**Yield Control.**—The control of yield, which in turn determines the weight per volume, is being given considerable study. Yield control in operation would be desirable from every angle. The consumer would have better possibilities of obtaining a more uniform ice cream, which in turn should increase consumption. The health and state officials would be better pleased, and the manufacturer would be merchandising his product on a much sounder business basis and preventing, or at least shortening the duration of, unprofitable price cutting and unfair competition.

Various devices are on the market to aid the operator in controlling his yield. While all have merit, none allows for the complete control of weight. This is not due altogether to the failure of the so-called overrun tester; it may be due to the structure of the mix, the construction of the freezer, and the carelessness of the operator. If the weight is to be controlled with any degree of accuracy, every step in the entire process must be given careful attention.

Judkins[25] shows, in his investigation of the weight of ice cream as it is manufactured in various commercial plants in the New England states, that none of the plants can guarantee that their standard 5-gal. cans of ice cream have a net weight within 1 lb. of each other. He concludes that it would require extreme vigilance to abide by a minimum weight standard per gallon. Among some of the factors mentioned as conducive to uniform weight are (1) one operator operating freezers of the same size and make, (2) not too many freezers for one operator, six with a hopper system, and three with the can system, (3) all freezers in charge of one operator running exactly alike, i.e., same brine flow and same speed, (4) proper brine temperature and circulation.

Turnbow,[26] in his investigation, which was confined to several California plants, found that one plant had a variation of 0.863 lb. per gallon in the first cans drawn, 0.542 lb. per gallon on the second cans, and 1.861 lbs. per gallon on the third. By the elimination of the broken or partly filled cans in the last lot drawn, the variation in weight of all cans would normally be 0.497 lb. per gallon. Although all the cream was pulled as near as possible to 100 per cent, as shown by the weighing-

[25] Judkins, H. F., Survey of factors involved in the manufacture and sale of ice cream. Ice Cream Review, April, 1926, p. 79.

[26] Turnbow, G. D., University of California Agr. Exp. Sta. Unpublished work.

type overrun tester, only 14 per cent of the first cans drawn fell in the actual 100 per cent class. The results obtained at all other plants paralleled these quite closely.

Stabler[27] has shown that it is possible to draw the first can with very little variation (0.07 to 0.1 lb. per gallon), and that it is impossible to control the weight of any can but the first. Greater uniformity of all cans is more nearly possible when the hopper system is used than when the ice cream is drawn directly into the cans. This is in general agreement with the work of Judkins, except that Stabler used the Draw-Rite Controllers in determining the correct time to draw.

There is a steady decrease in the weight of the ice cream as the yield increases. Just what the weight per gallon should be for any single percentage of yield depends upon the composition of the mix. On account of factors not under the control of the operator, the weight per gallon of ice cream varied in two commercial plants as given in the two following tables. In both cases weighing-type overrun testers were used, and the ice cream was drawn as near 100 per cent as possible. The main difference in the two creams is the percentage of total solids. The total solids of the mixes recorded in Table LV was 33.86 per cent; of those in Table LVI, 36.05 per cent.

The deviation in weight between the heaviest and the lightest first cans drawn in Plant 1 was 0.88 lb. per gallon, while in Plant 2 it was 0.53 lb. per gallon. The deviation in the weight of the first and the second can in Plant 1 covered a range from −0.47 to +0.25 lb. per gallon; in Plant 2, from −0.18 to +0.08 lb. Greater deviations were noted on runs frozen with the vertical than with the horizontal freezer. (Both types of freezers were in use in Plant 1.)

The wide deviation in the first can drawn in each of the plants is, no doubt, due to the inaccuracy of the weighing type overrun tester and the time elapsing between the time of making the test and the time the gate was opened for drawing. The mix is continually taking air as the whipping time is extended and during the early part of the drawing process. The amount depends upon the condition of the mix in the freezer. The rapidity with which a mix takes air depends largely upon the speed of the dasher, the viscosity, and the total solids in the mix. The greater the viscosity, the greater the resistance to a change in volume, all other factors being constant.

The solids in a mix serve as a framework. As the total solids are increased the proportion of free water is decreased. The increased

[27] Stabler, W. B., Control of Ice Cream Freezing, Ice Cream Review, February, 1926, p. 67.

TABLE LV

WEIGHT PER GALLON (COMMERCIAL PLANT I)

| Batch Plant | Run | First Can | | Second Can | | Third Can | |
|---|---|---|---|---|---|---|---|
| | | Size | Weight, Gallons | Size | Weight, Gallons | Size | Weight, Gallons |
| I | 1 | 5 | 4.60 | 3 | 4.29 | 2 | 4.56 |
| | 2 | 1 | 4.68 | 2 | 4.375 | 3 | 4.77 |
| | 3 | 5 | 4.63 | 3 | 4.45 | | |
| | 4 | 1 | 4.68 | 2 | 4.37 | 3 | 4.29 |
| | 5 | 5 | 4.88 | 3 | 4.5 | 2 | 4.37 |
| | 6 | 1 | 4.81 | 2 | 4.62 | 3 | 4.64 |
| | 7 | 5 | 4.48 | 3 | 4.47 | 2 | 4.28 |
| | 8 | 5 | 4.61 | 3 | 4.14 | 2 | 4.12 |
| | 9 | 5 | 4.22 | 3 | 4.08 | 3 | 4.0 |
| | 10 | 5 | 4.21 | 3 | 4.10 | | |
| | 11 | 5 | 4.57 | 3 | 4.54 | | |
| | 12 | 5 | 4.21 | 3 | 4.45 | | |
| | 13 | 5 | 4.16 | 3 | 4.16 | | |
| | 14 | 5 | 4.02 | 3 | 4.18 | 3 | 4.54 |
| | 15 | 5 | 4.25 | 3 | 4.50 | | |
| | 16 | 5 | 4.13 | 3 | 4.10 | 3 | 4.31 |

TABLE LVI

WEIGHT PER GALLON (COMMERCIAL PLANT II)

| Plant | Run | First Can | | Second Can | | Third Can | |
|---|---|---|---|---|---|---|---|
| | | Size | Weight, Gallons | Size | Weight, Gallons | Size | Weight, Gallons |
| II | 1 | 5 | 4.31 | 5 | 4.38 | | |
| | 2 | 5 | 4.16 | 5 | 4.08 | | |
| | 3 | 5 | 4.07 | 5 | 4.11 | | |
| | 4 | 5 | 4.32 | 5 | 4.38 | 1 | 4.06 |
| | 5 | 5 | 3.97 | 5 | 4.02 | 3 | 4.02 |
| | 6 | 5 | 4.57 | 5 | 4.51 | | |
| | 7 | 5 | 4.23 | 5 | 4.26 | 1 | 4.67 |
| | 8 | 5 | 4.12 | 5 | 4.06 | | |
| | 9 | 5 | 4.20 | 5 | 4.15 | | |
| | 10 | 5 | 4.38 | 5 | 4.26 | | |
| | 11 | 5 | 3.97 | 5 | 3.95 | | |
| | 12 | 5 | 4.17 | 5 | 4.10 | | |
| | 13 | 5 | 4.50 | 5 | 4.47 | | |
| | 14 | 5 | 4.05 | 5 | 4.0 | | |
| | 15 | 5 | 4.23 | 5 | 4.27 | | |

viscosity, due to an increased amount of total solids, is an aid in the retention of the air cells incorporated in the mix during freezing.

Table LVII takes into account viscosity, weights, brine temperature, and time required to freeze. The composition of the four mixes involved in this table varied but little from 11 per cent fat, 10.5 per cent milk solids-not-fat, 14.5 per cent sugar, and 0.5 per cent gelatin. All cans weighed were full. Since it was not possible to determine the volume in partly filled cans with any degree of accuracy, they were excluded. The ice cream was drawn as near 100 per cent as could be determined by a weighing-type of overrun tester. The first can may be controlled within very close limits by methods discussed later.

Table LVIII is a summary of Table LVII.

The variation in weight per gallon is shown in Table LVIII, which includes the weight deviation of all second and third cans drawn, the weight of the first can drawn in each respective run being used as a standard of comparison.

Eighty-eight per cent of all cans varied 0.20 lb. per gallon or more. Of the second cans drawn, 52 per cent showed a deviation no greater than 0.05 lb. per gallon. Of the third, only 14 per cent were in the 0.05-lb. class, and 48 per cent showed a variation below 0.20 lb. per gallon. Attention is directed particularly to the high percentage of the third cans drawn which exceeded 0.20 lb. per gallon. These figures can be accounted for by the time allowed for draining the freezer. The last can, in nearly all cases, is heavier than the first one drawn.

The viscosity of the mix going into the freezer affects the rapidity of obtaining the yield. The greater the viscosity in the finished ice cream, the less deviation in the weight per gallon. With the resistance to the incorporation of air, there will be a less rapid change in its density. Moreover, after the air is incorporated, such a mix will withstand the unloading process without much change in density.

In discussing standards for ice cream, officials very often mention the desirability of controlling yield, and in at least three states there is a law governing it. A weight standard also receives its share of discussion, but taken alone it is not fair nor does it offer protection to the consumer. A standard is primarily for the protection of the consumer. An enforced, just standard, if it is to be of value, in reality helps the scrupulous manufacturer more than anyone else. A just standard cannot be made without taking into consideration the food value. Most states have fat standards; some have total milk solids standards; and some, total solids standards; while practically all limit the use of stabilizers. The food solids per gallon must be considered when establishing a weight standard. Moreover, the fact that absolute control of weight is now impos-

TABLE LVII

FACTORS AFFECTING TIME TO FREEZE

| Batch | Run | Dasher Speed | | Total Time Required to Freeze | Brine Temp. into Freezer, ° F. | Brine Temp. Out of Freezer, ° F. | Capacity of Can | 1st Can | Capacity of Can | 2nd Can | Capacity of Can | 3rd Can | Viscosity of Mix, Poises |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Freezing | Whipping | | | | | | | | | | |
| 33 | 1 | 140 | 140 | 21′00″ | 2 | ....... | 3 | 5.04 | 5 | 4.76 | ....... | ........ | 3.12 |
| | 2 | 140 | 140 | 21′00″ | 2 | 8 | 3 | 4.65 | 5 | 4.83 | | | |
| | 3 | 71 | 211 | 22′00″ | 2 | 8 | 5 | 4.59 | 4 | 4.63 | | | |
| | 4 | 71 | 211 | 19′35″ | −1 | 4 | 3 | 4.38 | 5 | 4.28 | | | |
| | 5 | 71 | 211 | 15′45″ | −1 | 3 | 5 | 4.32 | 4 | 4.42 | | | |
| | 6 | 71 | 211 | 14′50″ | −1 | 3 | 3 | 4.31 | 5 | 4.26 | | | |
| | 7 | 106 | 211 | 17′45″ | −1 | 3 | 3 | 5.04 | 5 | 4.30 | 2 | 4.23 | |
| | 8 | 106 | 211 | 15′45″ | −1 | 3 | 3 | 4.40 | 5 | 4.42 | 1 | 4.7 | |
| 37-X | 1 | 106 | 211 | 19′20″ | 0 | 5 | 5 | 4.28 | 5 | 4.30 | ....... | ........ | 5.77 |
| | 2 | 140 | 211 | 16′32″ | 0 | 5 | 5 | 4.36 | 3 | 4.43 | | | |
| | 3 | 140 | 211 | 17′34″ | 1 | 6 | 5 | 4.56 | 5 | 4.45 | | | |
| | 4 | 140 | 211 | 18′15″ | 1 | 5 | 5 | 4.34 | 5 | 4.28 | | | |
| 18-A | 1 | 140 | 140 | 20′00″ | −2 | 7 | 3 | 4.43 | 5 | 4.54 | ....... | ........ | 6.63 |
| | 2 | 140 | 140 | 18′55″ | −2 | 6 | 3 | 4.40 | 5 | 4.58 | | | |
| | 3 | 140 | 140 | 17′45″ | −2 | 6 | 3 | 4.40 | 5 | 4.44 | | | |
| | 4 | 140 | 140 | 18′40″ | −2 | 6 | 3 | 4.30 | 5 | 4.50 | 2 | 4.7 | |
| | 5 | 140 | 140 | 21′15″ | −2 | 6 | 3 | 4.46 | 3 | 4.56 | 3 | 4.6 | |
| | 6 | 140 | 140 | 22′20″ | −2 | 6 | 3 | 4.26 | 3 | 4.36 | 2 | 4.55 | |
| 37 | 1 | 211 | 211 | 16′07″ | 1 | 8 | 5 | 4.25 | 5 | 4.37 | 2 | 4.72 | 7.17 |
| | 2 | 211 | 211 | 16′05″ | 0 | 8 | 5 | 4.32 | 3 | 4.38 | | | |
| | 3 | 211 | 211 | 18′02″ | 2 | 10 | 5 | 4.32 | 3 | 4.32 | 2 | 4.74 | |
| | 4 | 211 | 211 | 17′50″ | 2 | 11 | 5 | 4.30 | 5 | 4.20 | | | |
| | 5 | 211 | 211 | 15′50″ | 2 | 6 | 5 | 4.20 | 5 | 4.45 | | | |
| | 6 | 211 | 211 | 16′02″ | 1 | 7 | 5 | 4.33 | 5 | 4.78 | 2 | 4.78 | |

sible must be borne in mind. Therefore, the standard must be low enough to care for the uncontrollable variations, and must work on a sliding scale to take into account changes in allowable total solids. Any increase in milk solids, either in fat or in milk solids-not-fat, will increase the food value at a given per cent of yield and will produce a uniform, more palatable ice cream. Furthermore, such a mix can be frozen with less variation in yield.

TABLE LVIII

VARIATIONS IN WEIGHT OF CANS DRAWN

| Variation, Pounds per Gallon | Per Cent Total Second Can | Per Cent Total Third Can |
|---|---|---|
| None | 12 | 5 |
| 0 to ±.05 | 40 | 14 |
| ±.05 to ±.1 | 9 | 9 |
| ±.1 to ±.15 | 17 | 19 |
| ±.15 to ±.20 | 9 | 1 |
| ±.20 above | 12 | 52 |

The only fair and accurate method of determining the weight of ice cream in a container is to weigh and subtract the tare. California regulations have a food solids standard which is really a weight standard. All cans must bear a tare in pounds and ounces. The inspector weighs the can, subtracts the tare, and has immediately the net weight per gallon. A sample of the cream is analyzed for fat and total solids. This standard calls for an average of 1.6 lbs. food solids per gallon, of which 10 per cent must be butterfat. In other words, an ice cream made from a mix containing 36 per cent total solids must weigh, on the average, 4.44+ lbs. per gallon in order to deliver 1.6 lbs. of food solids. A mix containing 40 per cent total solids would have to weigh only 4 lbs. per gallon in order to deliver 1.6 lbs. of food solids. In determining this weight under inspection conditions, a minimum of 30 cans, or if fewer are present, the whole number, must be weighed; and they must average 1.6 lbs. of food solids per gallon. The composition of the mix under this law is quite closely controlled. A manufacturer who is putting in a small amount of solids, and consequently a greater proportion of water, must take less overrun, which gives him a heavier weight per gallon but a uniform amount of food solids per given volume. This is a highly desirable regulation. The consumer is interested primarily in two things: a clean, sanitary, wholesome product, and a uniform amount of ice cream per dollar expended. The weight per gallon, or the amount

of air that the ice cream contains is of no particular interest to the consumer if he is receiving the two factors referred to above. Whether or not he has obtained the first is determined largely by the bacteria count of the ice cream. (In California 150,000 is the maximum.) The second is calculated by determining the food solids per gallon. It is only a matter of time until all ice cream will be sold on this or a very similar basis. It can be done, but the ice cream manufacturer must give more attention to the freezing process. Much care has been given in the past to the construction and quality of the mix and to its ingredients, and too little to the freezing process, which largely determines the quality of the cream that the consumer is to receive. There is an exact time—different for every mix—at which the freezing medium should be turned off. Regardless of this fact, each mix should be frozen to such a consistency that, when the freezing medium is turned off, sufficient air has been or may be incorporated to produce the desired texture and at the same time to deliver the ice cream to the container in as firm and as nearly frozen condition as possible without requiring too much time for the unloading process. It is possible to have a 100 per cent yield, if that is the figure desired, and yet have an ice cream too stiff for economical handling when it arrives at the container. Again, an ice cream containing 100 per cent yield may be drawn to the can in a very soft condition. The former condition necessitates time for unloading and consequently results in variation in density. The latter, while it enables very rapid unloading, may result in the formation of large crystals during the hardening process. Furthermore, air cells may migrate in the can before the ice cream has time to harden sufficiently in the hardening room. Air cells often collapse, forming a large cell structure. All this will result in a rough, coarse texture. With certain types of freezers and mix construction, sufficient air can be incorporated by the time the ice cream is hard enough to draw from the freezer. In such a case no whipping takes place other than that occurring during the freezing process. In other words, the whipping and freezing processes occur simultaneously.

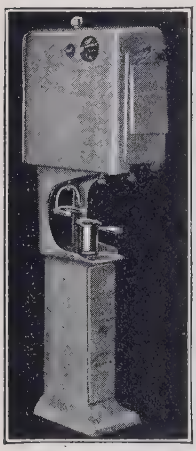
In other types of freezer and mix construction, the mix is frozen sufficiently stiff before the desired amount of air has been incorporated. It is the usual practice in such cases to turn off the brine or freezing medium at this point and whip in the desired amount of air or gas, and to draw the cream from the freezer as soon as it has reached the desired percentage of overrun or yield.

Still another practice, not used frequently in recent years, is to whip in more air than is desired and then turn on the freezing medium and freeze back to the desired percentage. This method of freezing requires one to three minutes longer.

This method of freezing can hardly be recommended, however, for the extra time required is not justified by the quality of cream obtained. As a matter of fact, by using a high-solids mix and cold brine, the ice cream may be drawn as soon as the desired yield is reached and a product of equal quality obtained. Various methods have been devised for determining the time to turn off the freezing medium and the time of drawing the ice cream from the freezer. These have resulted in the production of a more uniform ice cream by giving the operator an idea of the condition of his ice cream at all times and by calling his attention to the fact that uniform ice cream is the result of uniform yields.

**Mojonnier Overrun Tester.**—The Mojonnier Overrun Tester, by which the percentage of overrun may be read directly, is operated in the following manner:

Assuming that the scale is level and in good working condition, the cup is filled with mix, the lock on the bottom of the cup having been loosened and hung on the tree of the scale. The reading on the scale at this point should be zero. If it is above zero, more mix should be placed in the cup. The volume of the cup can be increased for this purpose by screwing down the lock mentioned above. Care should be taken each time to strike the cup off level at the top with a blade or a spatula. If the reading on the scale is below zero, the bottom should be screwed up, thus decreasing the volume until exactly zero is reached, when the lock nut should be tightened again so that the adjustable bottom will not move. Empty the mix into the freezer, wash the cup, and the tester is ready for operation.



*Courtesy Mojonnier Brothers*
Fig. 55. — Weighing Type Overrun Tester.

During the freezing process, samples may be taken with the cup, and the cup struck off level with the top and hung on the scale, where the percentage or decrease in weight is read direct. Though this test gives a very good indication of the weight of a gallon of ice cream, it must be remembered that a small error in the sample means a considerable error in the weight per gallon.

The table below represents sixteen consecutive runs on the same mix. A weighing-type overrun tester was used and the ice cream was drawn from the freezer as near 100 per cent as could be determined by this method.

It will be noted that the lightest can was a 5-gal. container weighing 4.025 lbs. to the gallon, and that the heaviest, also a 5-gal. can, weighed

4.888 lbs. to the gallon, representing a variation between the lightest and the heaviest of 0.863 lb. to the gallon. Tests covering some 8000 gals. of ice cream showed similar variations. No overrun tester can control the variation in weight per gallon of the second and subsequent cans drawn from a single run. The best that can be expected from such a device is an indication of the correct time to begin the drawing process. Since the change in density is very rapid when the yield is at approximately 100 per cent, the time required to take the sample, strike the cup, weigh, make the mental note, and return to the freezer, is too great to assure the operator that the weight per gallon in the first can drawn, will be the same as that indicated by the cup.

TABLE LIX

VARIATION IN DENSITY OF FIRST CAN DRAWN

| Capacity of Can | Gallons of Ice Cream in Each Can | Weight per Gallon |
|---|---|---|
| 5 | 5 | 4.163 |
| 5 | 5 | 4.488 |
| 5 | 5 | 4.213 |
| 1 | 1 | 4.813 |
| 5 | 5 | 4.225 |
| 5 | 5 | 4.575 |
| 5 | 5 | 4.025 |
| 5 | 5 | 4.613 |
| 5 | 5 | 4.213 |
| 5 | 5 | 4.888 |
| 5 | 5 | 4.250 |
| 1 | 1 | 4.6875 |
| 5 | 5 | 4.463 |
| 1 | 1 | 4.688 |
| 5 | 5 | 4.138 |
| 5 | 5 | 4.60 |

One method of filling the cup should be employed wherever a weighing-type overrun tester is used. Three different plants inspected used three separate methods of filling the cup. At one plant, the cup was filled and struck off level with the top. At another, a spatula was inserted two or three times after the cup was filled, with the idea of eliminating any air pockets that might have been entrapped. At the third, the bottom of the cup was struck several times on the edge of the freezer, with the idea of packing the cream more firmly into the cup. With the

cream at a certain consistency, these methods are bound to give different readings. Again, even though a uniform method is used by the operator, the consistency of the cream at the time of filling the cup will influence the amount required for this purpose. A very stiff mix will fold into the cup, entrapping air pockets, while a very soft one will fill it completely. This inconsistency, of course, could be avoided if the freezing medium were turned off at the same point each time, giving a uniform consistency of cream in the can.

Some ice cream makers do not wholly approve of overrun testers or controllers. They feel that after years of experience they can guess the density of the ice cream by observation. In actual practice, this has some merit, but it is entirely dependent upon the skill of the operator and the type of freezer and mix with which he is working. But even under the best of conditions, this method is entirely too inaccurate for the production of uniform ice cream. Even with the use of a scale, it is impossible, for reasons already pointed out, to control the density of the first can drawn within a narrow enough margin to produce an ice cream that is actually uniform. There undoubtedly is a correct percentage of yield that will produce the best quality of ice cream. A manufacturer may be obtaining, on the average, the desired yield for the proper returns on his plant; but an accurate determination of the density of the cream in his hardening box may show that a considerable percentage of the cans are below or above the average yield, there being, of course, another percentage having the exact density desired. If the best quality of cream is obtained with the lightest density, then the manufacturer is overlooking returns to himself and a portion of his product is entirely too heavy. This condition, however, is usually not the case. Even though the tendency is to push the upper limit of yield, the manufacturer is producing a considerable quantity of ice cream that would really be better if the yield were a little greater, and, on the other hand, a considerable portion is entirely too light for the best quality of product.

Fig. 56 represents what might be expected from the use of a weighing type overrun tester in controlling the density of the ice cream. This graph represents several hundred gallons of ice cream drawn in a commercial plant. Every known effort was made to begin the drawing process at exactly 100 per cent.

The mix contained 10.5 per cent fat and 36.05 per cent solids; 40-qt. freezers were used. The capacity of the cans included 5's, 3's, 2's, and 1's. The variation in weight in the second, third, and fourth cans cannot be attributed to the overrun tester. The best that can be expected of an overrun tester or controller is the indication at the time to start the drawing process. Better control can be had where cans as

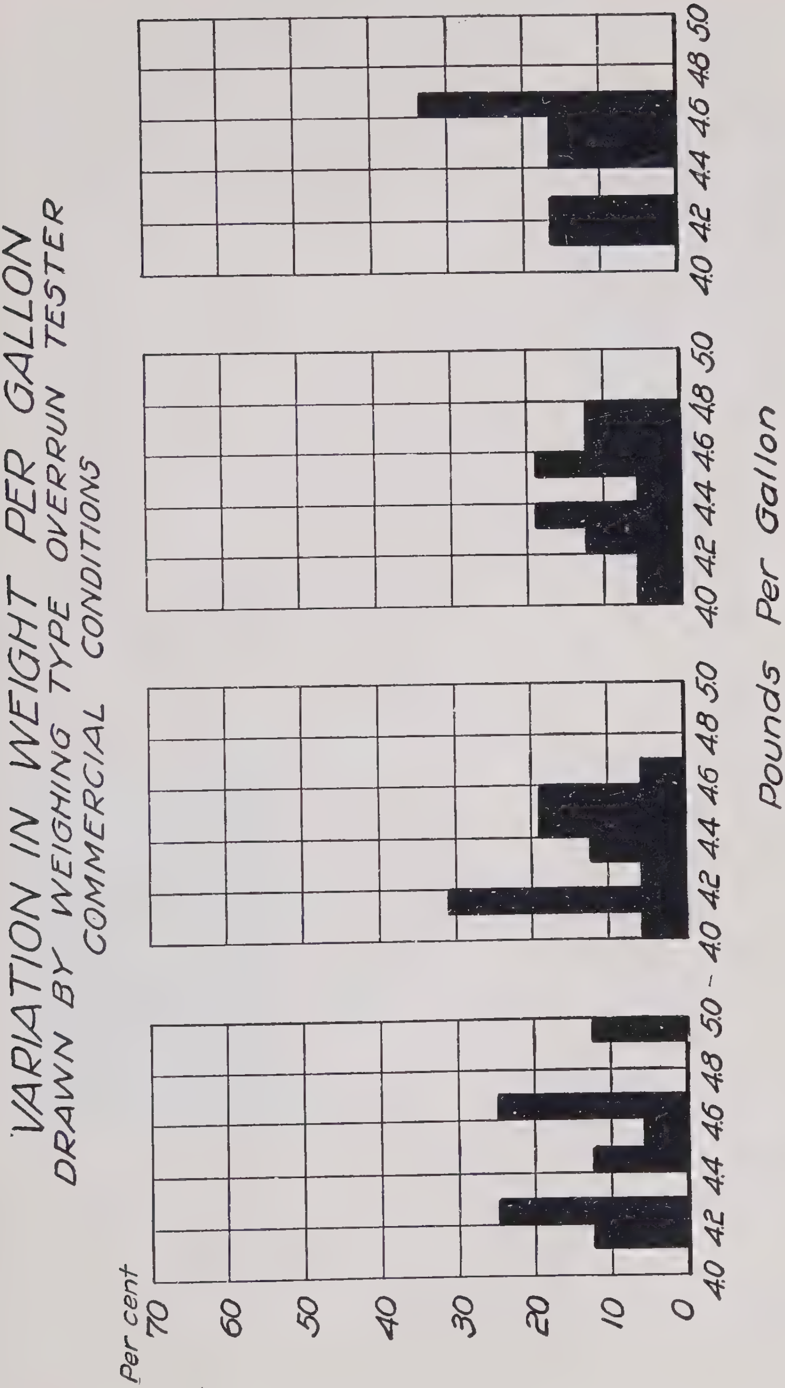

VARIATION IN WEIGHT PER GALLON
DRAWN BY WEIGHING TYPE OVERRUN TESTER
COMMERCIAL CONDITIONS
Per cent
70
60
50
40
30
20
10
0
4.0 4.2 4.4 4.6 4.8 5.0
4.0 4.2 4.4 4.6 4.8 5.0
4.0 4.2 4.4 4.6 4.8 5.0
4.0 4.2 4.4 4.6 4.8 5.0
Pounds Per Gallon

Fig. 56.

large as 5's are drawn. One's are more conducive to variation in density.

Regardless of the type used, the scale must be kept in condition. Scales are often found reading as much as 10–15 per cent off. Even if the method were perfect and this type of technique were used, the operator could not expect to control the density of the first can drawn. The time has passed when slip-shod methods can be used during the freezing process. Unless manufacturers come to realize that this process is just as important as any other step in the production of ice cream, laws will be made to force them to take the necessary steps to obtain uniformity. Any manufacturer will say that he is doing this now, but in a good many cases his statement cannot be backed up by facts.

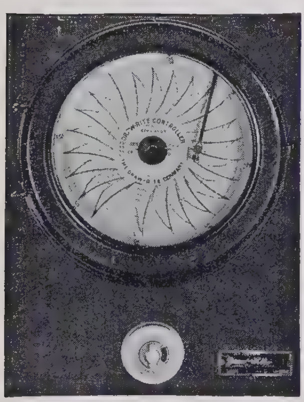
There are other makes of overrun testers on the market, which operate on the same principle as the Mojonnier, and some of which are very easy to operate. They are known as the Torsion, the Sommer, and the De Raef.

**Willman Controller.**—An instrument of a somewhat different type is the Willman Controller. This controller works upon the basis of temperature. A bulb is inserted into the freezing chamber; when the ice cream is frozen to a certain temperature, contact is made by lighting a light. The operator then turns off his brine or freezing medium and whips to the desired point. Obviously, during the whipping process there is an increase in temperature, which is noted on the instrument by another light flash. There is a time element here, which allows for the incorporation of the air. To be satisfactory, each freezer must be equipped with a controller. It is impossible to synchronize the freezing process, when only one instrument is installed on a battery of freezers. It is very doubtful that any two freezers work exactly alike under the installations that they must receive in a commercial plant. The brine temperature, even though it varies but slightly, will affect the time required to freeze. If the freezing medium is turned off at the time indicated by the first freezer, the last will probably be a little too soft, while others will be a little too stiff; and the result as a whole will be a non-uniform yield. If this type of installation is used with each freezer and checked daily—not a difficult task—very good control of the first can drawn may be had.

This type of instrument has an added advantage over those mentioned above in that it gives a record of the number of batches frozen, the time required to freeze, the hours during which the freezers were in operation, and considerable additional information which is very desirable to the manufacturer.

**Draw-Rite Controller.**—Another type of freezing controller is known as the Draw-Rite. This operates upon resistance. The motor and motor load are suppressed on the dial so that only changes in the freezing process are shown. It is no more possible to synchronize the freezing with the Draw-Rite than with the Willman. This type of freezing controller should be referred to as a duplicator rather than as a controller, and should be installed on each machine. Because of the age of the mix, the variations in composition, the source of those materials that undoubtedly change the salts, which in turn have a marked effect upon the freezing process, it is impossible to duplicate the yield from day to day, with any type of controller, without slight adjustments. Every operator knows that the first run from the freezer of the day's run does not give the desired "gallonage," even though the weight per gallon is correct. There is a certain amount of cream that stays in the freezer, sticking to the dasher; each successive run, however, should give the desired volume. It may be necessary, if the cream is coming a little soft from the freezer, to freeze half a point higher or a half a point lower, in order to get the proper yield. After the Draw-Rite is once set for the day, there should be no further changes; it is possible to duplicate each successive run on that freezer by turning off the brine or freezing medium and drawing at the same points. In the past, the drawing point was considered all-important, and so it is; but in order to approach more closely a duplication of it, the cream must be frozen to the same stiffness each time.


*Courtesy of Draw-Rite Company*
FIG. 57.—Indicating Draw-Rite.



*Courtesy of Draw-Rite Company*
FIG. 58.—Recording Draw-Rite.

In the operation of the Indicating or Recording Draw-Rite, the mix is frozen to, for illustration, 9, when the freezing medium is turned off; the mix is whipped to 6, at which time the drawing process commences. It should continue to some definite point, 2, for example. The three steps in the freezing process, as indicated by the Draw-Rite, would then be as follows: First, the freezing medium should be turned off at the right time, thereby producing a uniform stiffness to the can. The ice

cream should be as stiff as possible, and still facilitate the rapid emptying of the freezer. The more water that is frozen in the freezer under agitation, the smoother the ice cream; if too much is frozen in, however, too much time will be required for emptying, and as a result an unusually large variation in weight will occur. The second step in the process necessitates the drawing of the ice cream at exactly the right time. As has been stated before, above 80 per cent the mix or emulsion becomes so unstable that rapid changes may take place. This is especially true up to 100 per cent. The incorporation of air from 100 to 120 per cent is slower than from 80 to 100 per cent, with an average mix. So many things may be done to change this rate of air incorporation that definite methods cannot be given; therefore, it is very necessary that the "man at the freezer" attend strictly to business, so that each freezer may start its emptying process at exactly the right time. Delay of the emptying process is one of the reasons that the weighing type of overrun tester does not work out more accurately in practice.

For the production of uniform ice cream, the freezing medium should be maintained at one constant temperature. For this and other reasons, the direct-expansion freezer has great possibilities. The manufacturer of uniform ice cream requires that the freezing temperature be maintained. With the Willman or Draw-Rite, it is very necessary that the freezing medium be quite constant. However, a scale can be made so that for each 3 or 4 degrees' change in brine temperature, a certain setting can be made on the controllers. In both cases, there would be more time allowed for the incorporation of air during the freezing period where warmer brine was used than where zero or even colder brine was used. If the brine temperature is increased within a reasonable limit, the whipping time is decreased. One advantage of the last two types of controllers mentioned is that there is nothing to wash.

The Draw-Rite is made in two styles: the Recording and the Indicating. Under normal operating conditions, the needle on the Draw-Rite should retard immediately upon the turning off of the freezing medium. In case it does not, one of two conditions undoubtedly exists: there is a leaky brine valve, so that, even though the valve is turned off, the freezing has not actually stopped, or the scraper blades are dull, thus allowing the accumulation of a layer of frozen cream on the inside of the chamber. When the freezer is working properly, there should be a half or a whole point drop immediately after the freezing medium is turned off. If there is much oscillation of the needle during the freezing period, the bearings of the freezer or the condition of the blades is very likely to be the cause. Good electrical connections are, of course, necessary for the economical consumption of electricity. Poor connections will often be indicated on the Draw-Rite toward the end of the whipping

period, at which time the needle may start to climb slightly, even though the incorporation of air is continuing. These poor connections are either in the instrument itself or in the line leading to the motor. The indicating machine should be placed near each freezer or at some convenient place about level with the height of the eye, so that it can be used with the highest degree of efficiency.

**Weight Control.**—The Crescent Creamery Company of Los Angeles, under the supervision of Mr. William Stabler, accumulated data under simulated experimental conditions. The following graph indicates what may be expected when all steps are carefully checked.

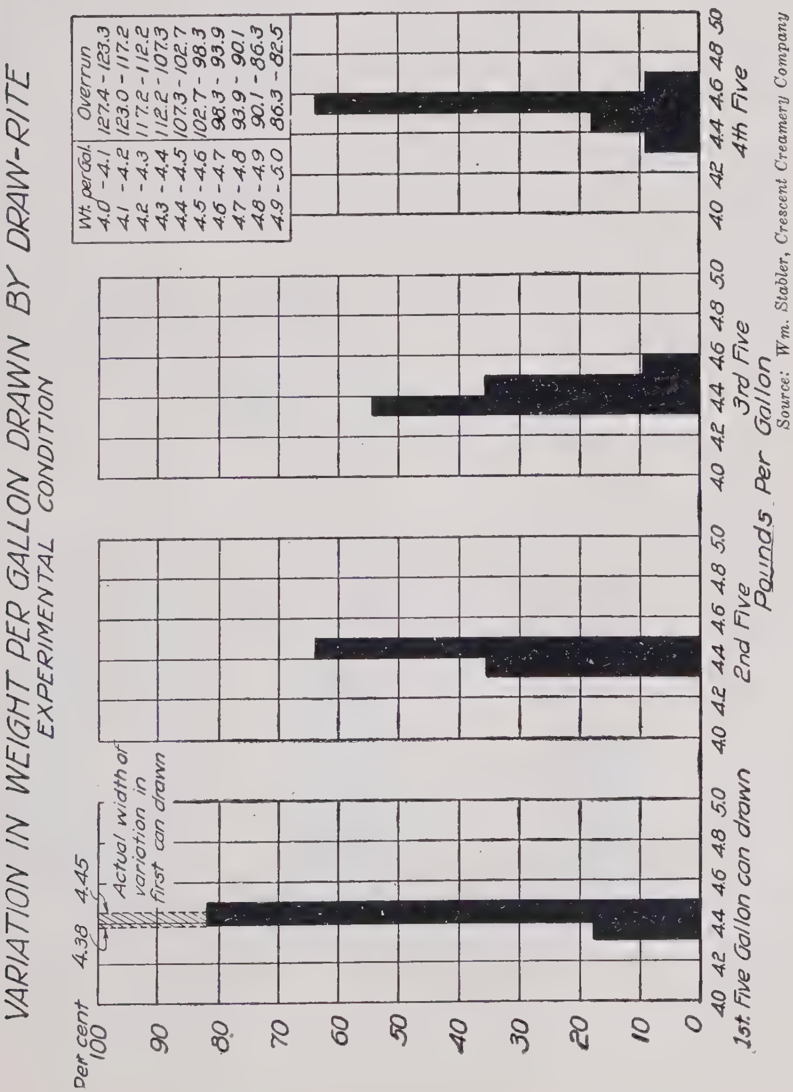


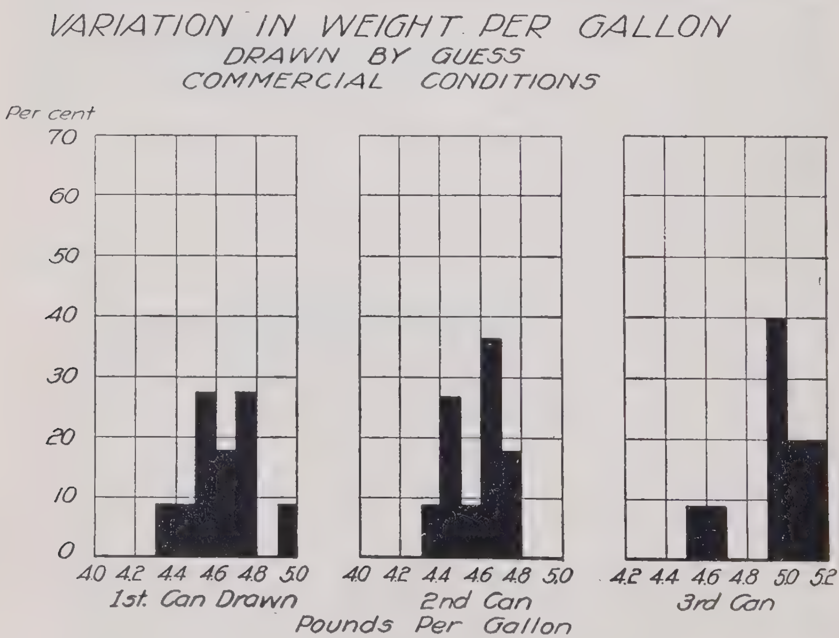

Fig. 59.

Regarding the manner in which he secured the data shown in Fig. 59, Mr. Stabler says:

Two 80-qt. freezers were selected, the instruments checked and reset to accommodate the lighter load on the power lines. The mix was weighed into the hoppers, and everything was done to surround the work with as nearly ideal conditions as possible. Under these conditions, the graph shows that 83 per cent of the gallons from the first cans fell within the 4.4–4.5 lb. division, and 18 per cent in the 4.3–4.4 class. Closer inspection of the figures shows that 100 per cent of the first cans fell in a variation band of only 0.07 lb. per gallon. This is shown in the shaded portion beside and above the first column. This band widens on the 2nd, 3rd and 4th cans as indicated by the graph. The figures when put in the curve, show the same characteristics as those just previously shown. Exact influence of the human equation is difficult to obtain, but under rigid experimental conditions we were able to reduce the band of variation from 0.3 lb. per gallon to 0.07 lb. per gallon on the first cans drawn.

It cannot be expected that the weight of the first can can be controlled as closely under commercial conditions as would be the case under experimental conditions. Furthermore, the number of cans drawn influences the variation in weight.

Fig. 60 illustrates what can be done in regular commercial manufacture.




*Source: Wm. Stabler, Crescent Creamery Company*

Fig. 60.

Mr. Stabler says, further:

Figure 61 was made up from the data collected on regular runs of battery of five 80-qt. freezers, drawn when the Draw-Rite instrument indicated it was time to draw, and under regular factory conditions. The cans were carefully weighed to the nearest ounce before filling, scraped level after filling, and again weighed to the nearest ounce. Charts on drawing 5-gal. cans and 3-gal. cans are shown separately. Mix contained 10.5 per cent fat, 36.20 per cent total solids, and weighed 9.124 lbs. per gallon, and we attempted to draw cream at 4.5 lbs. per gallon. How nearly we realized our intentions is graphically shown in the chart.

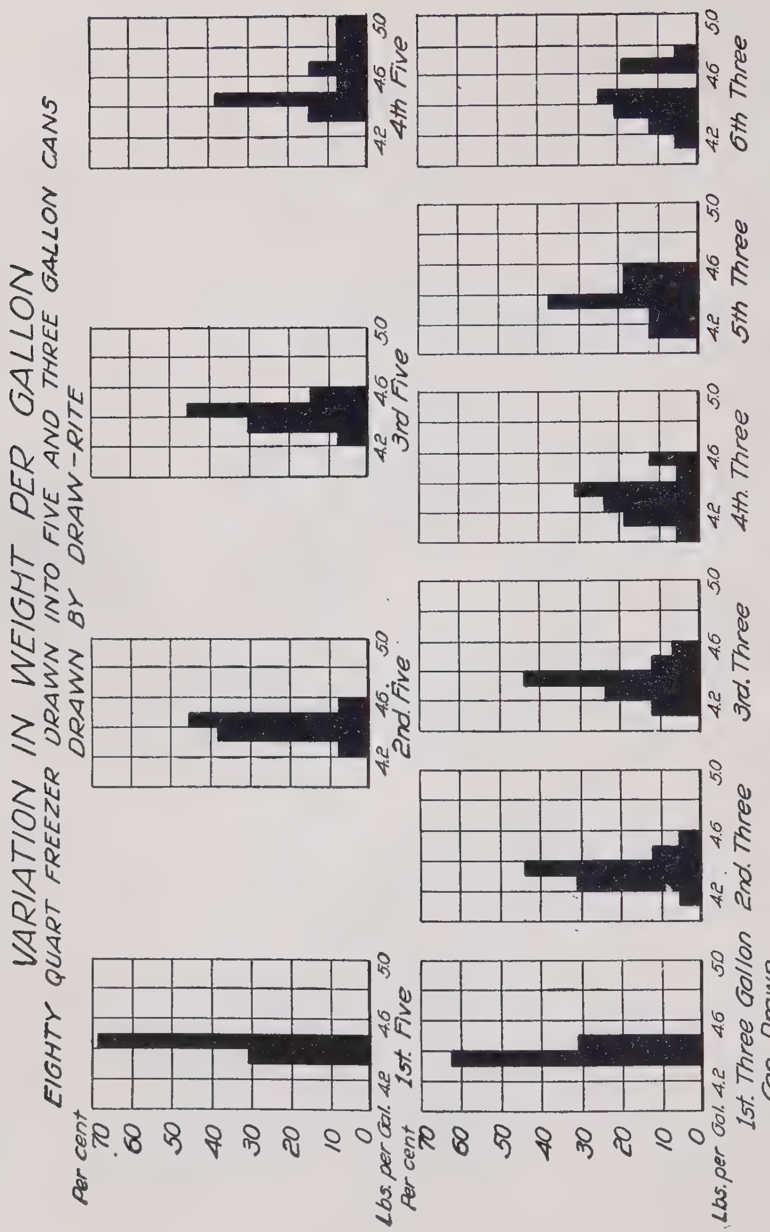
You will notice that 69 per cent of the gallons drawn in the first 5 gals. weighed between 4.4 and 4.5 lbs. per gallon, and that 31 per cent fell in the class between 4.3 and 4.4. The maximum band of variation was 0.2 lb. per gallon.

In the second cans drawn, 47 per cent weighed less than 4.4 lbs. and only 53 per cent weighed more than 4.4 lbs. per gallon against 68 per cent in the first cans drawn, with a maximum variation of 0.4 lb. per gallon, and 8 per cent weighed more than 4.5 lbs. per gallon.

In the third cans drawn, approximately the same per cent of gallons fell in the 4.4 to 4.5 lbs. class as in the second cans, but 16 per cent were heavier than the 4.5 lbs. and 38 per cent were lighter than 4.4, against 47 per cent lighter in the second cans. The band of variation still remains the same in the third cans as it did in the second. The variation lighter than 4.4 is 0.2 lb. in both second and third cans and only 0.1 lb. heavier than 4.5 lbs.

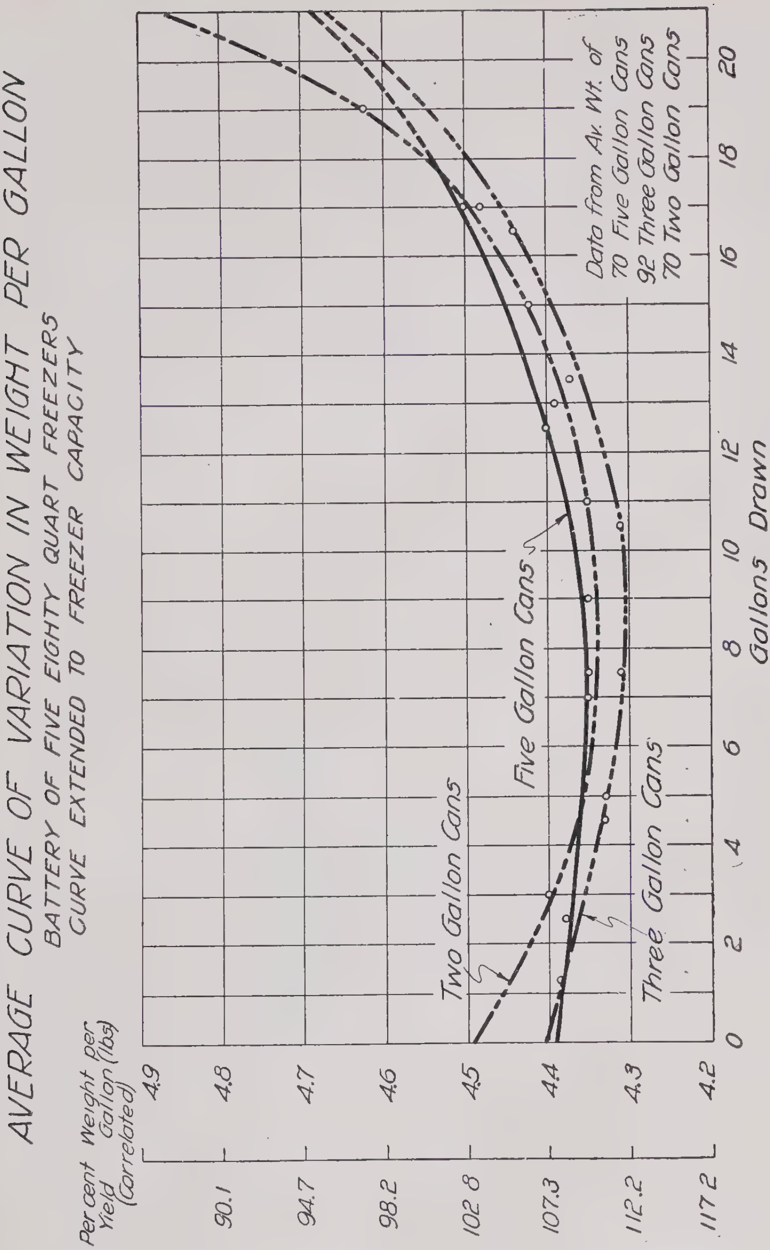
In the fourth can group, 38 per cent remain in the 4.4 and 4.5 group, and 47 per cent were heavier than 4.5 and 15 per cent lighter than 4.4. The total band of variation was 0.7 lb. per gallon but only 0.1 lb. variation higher than 4.4 and 0.5 lb. heavier than 4.5.

These data bring out what may be expected during the drawing of each succeeding can. Assuming that the first can is drawn at the desired weight, the second can will be considerably lighter, while each succeeding one will tend to become heavier. This is true where the mix is frozen to a certain consistency and then whipped to the desired percentage of yield. It may not be true if the cream is whipped to a percentage higher than that at which it is desired to draw, and then frozen back. This is shown in the following two graphs. The Draw-Rite Controller enables the operator, under good factory conditions, to draw the first gallon of ice cream with 0.1 lb. variation from the first gallon in the succeeding batch. Changes take place faster than the finished product can be drawn. They can be explained by the fact that as the first can drawn still leaves the mix above the beater, the incorporation of air increases quite rapidly. The freezer was undoubtedly full or nearly so at the time the drawing process began. This also explains why the incorporation of air above 100 per cent is somewhat slower than from 80 to 100 per cent.



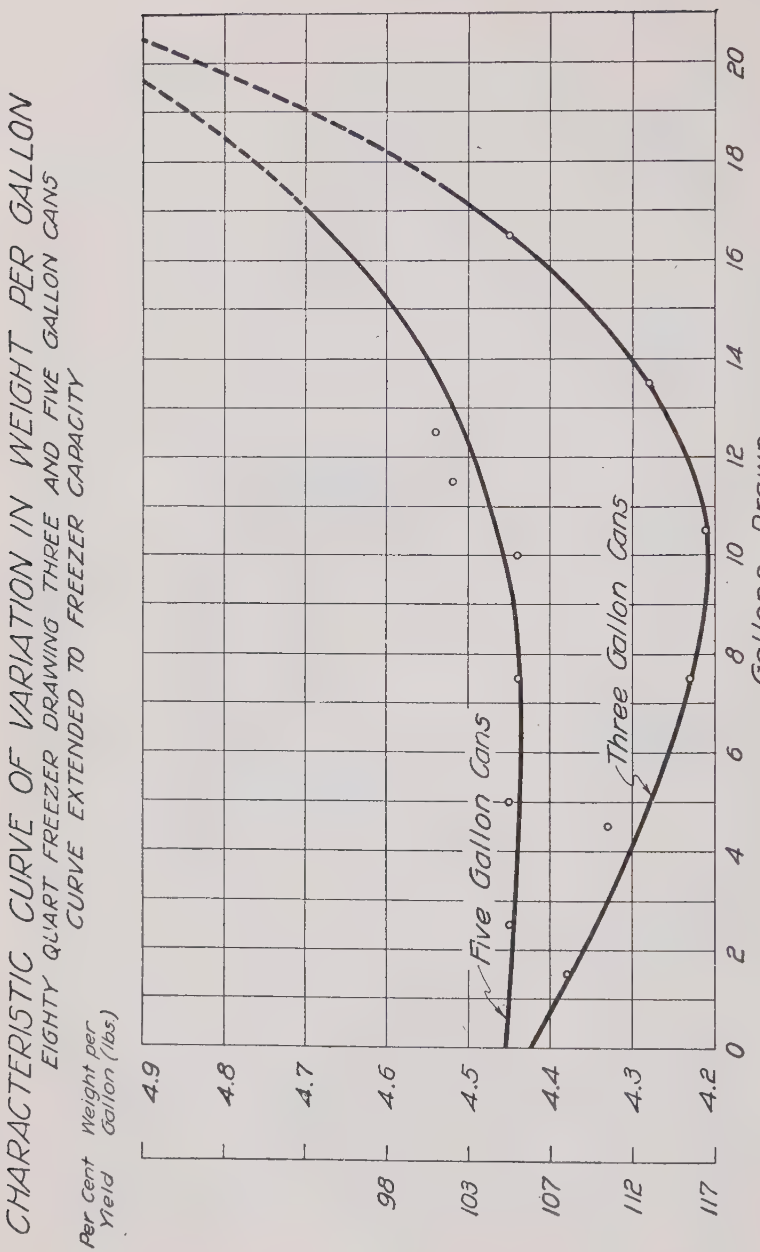

Source: Wm. Stabler, Crescent Creamery Company

Fig. 61.




Source: Wm. Stabler, Crescent Creamery Company

Fig. 62.




Source: Wm. Stabler, Crescent Creamery Company

FIG. 63.

When the second can is drawn, the beater blades become exposed and the air is immediately beaten out of the cream, thereby decreasing the yield and increasing the weight. This condition can be almost entirely eliminated, even with the present freezer, if it is remodeled so that separate control of the beater is maintained. This control of the beater may be accomplished in two ways, with separate motor control or with a transmission. Whichever of these is used, it must be under the control of the operator.

The more time elapsing during the drawing process, the greater the difference between the weight of one gallon and that of another.

**Increased Total Solids and Weight Control.**—The data above regarding the weight control refer more specifically to ice cream mixes containing approximately 36 per cent total solids. Any increase in total solids tends to produce a more stable emulsion and less variation in the weight control. The more stable the emulsion, the less it is subject to the mechanical action of the freezer during the unloading process. Mixes were made up containing the following percentages of total solids: 33.8; 36; 41, and 46. The increase in solids above 33.8 per cent was due entirely to additional milk solids-not-fat, and was obtained by a special method, so that an increase of more than 11 per cent was made without producing "sand" under normal marketing conditions. An ice cream mix containing the usual amount of butterfat and a slight decrease in the percentage of gelatin, with $\frac{1}{2}$–1 per cent increase in cane sugar (sucrose) and a total of 15–15.5 per cent of milk solids-not-fat, produces a satisfactory ice cream.

A mix with the composition suggested above will contain nearly 41 per cent total solids; the curve shown in Fig. 64 indicates the stabilizing effect of increased milk solids-not-fat. This greater stabilization undoubtedly aids materially in holding the air *in situ* during the unloading process, the solids being more resistant to variation than the water which they replace.

Two to $2\frac{1}{2}$ lbs. of additional milk solids in special powder form are added at the freezer to 45 lbs. of mix, which has originally been made up as suggested above. This amount gives excellent results as regards smoothness in texture, closeness in body, fineness of the air cells, and freedom from iciness; in addition, it allows the incorporation of more air, still maintaining a constant in the food solids.

An ice cream containing, for example, 40 per cent total solids, of which all above 36 per cent were secured from the use of special skim-milk solids, so manufactured and handled as not to produce sandy ice cream, would produce, under the California Law, an ice cream weighing, on the average, 4 lbs. per gallon, and still deliver the required 1.6 lbs.

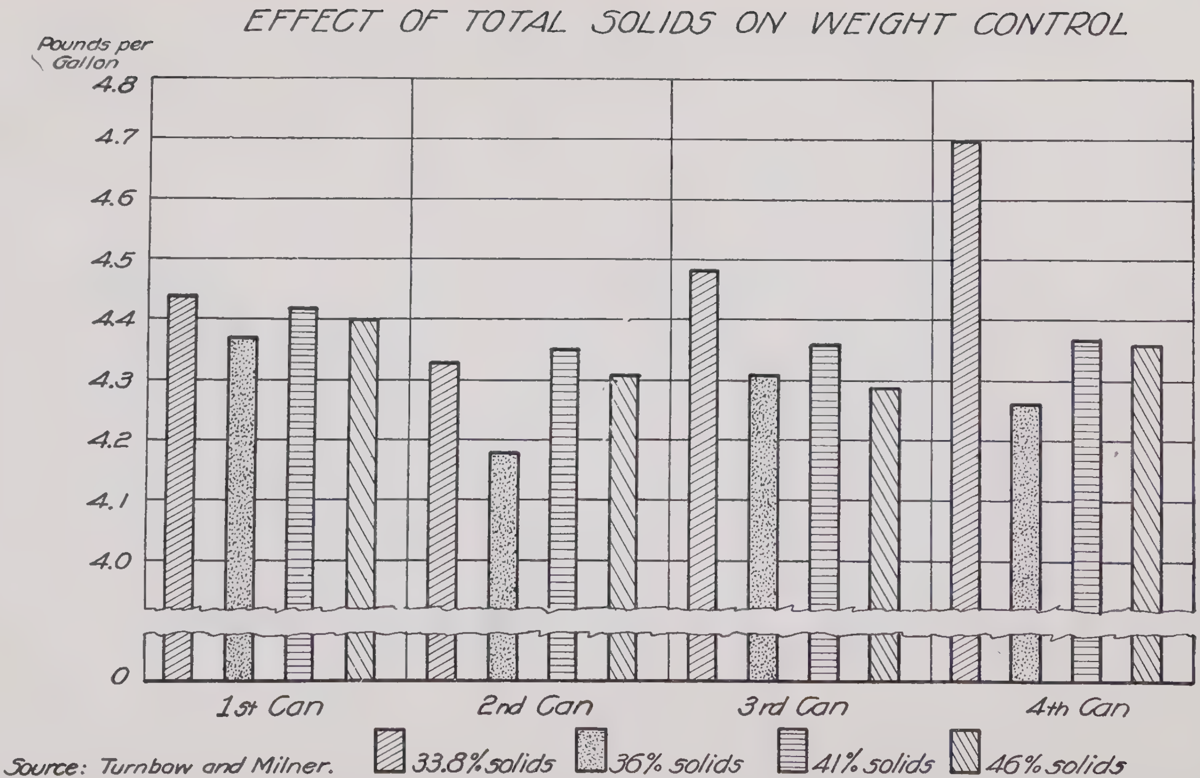



FIG. 64.—As the Total Solids of the Mix Are Increased the Variation in the Density of the Frozen Product Decreases.

of food solids. If a more palatable product, equal in stability and in food value to one with lower solids, could be secured, the consumer would have no complaint.

**Food Solids per Gallon.**—In the experiments plotted in Fig. 64, no attempt was made to deliver the same amount of food solids per gallon in the first cans. Mix No. 1 contained 33.8 per cent total solids; No. 2, 36 per cent total solids; No. 3, 41 per cent, and No. 4, 46 per cent. It is evident that the mix containing the higher solids, with the weights as illustrated in this graph, delivered more food solids per gallon. It is also quite evident that the higher the solids, the less the variation in weight per gallon during the drawing period. All of these weights represent averages. Since some weights were below and some were above these figures, a standard could not be drawn on the basis of averages without taking into consideration the lighter cans.

As shown by the curves in Graph 3, an attempt was made to draw the ice cream at such a weight as to deliver approximately the same percentage of food solids to the gallon in the finished ice cream. The first can drawn represents the average weight, as do all of the other cans.

The third can drawn, from mix No. 4, which contained 46 per cent total solids, shows a little greater average variation than the third can of 41 per cent solids. While the total of all these data represents a comparatively large number of gallons (approximately 2000), it is possible in No. 4, which represents only 80 gals., that this quantity allows for weight variations, or that the solids have reached such a point as to cause the mix to become brittle and lose some of its stability rather than retain it as did mix No. 3, containing 41 per cent total solids.

**Weight Standard and Food Solids.**—Fig. 64 illustrates the desirability of a weight standard that is closely connected with the total solids in the mix. A standard that attempts to control yield is an injustice, in that it discourages the use of high solids, which undoubtedly will be used in the next year or so to a much greater extent than at the present. Anything that discourages the increasing of the food value per given volume of ice cream is not sound. Simply to have a weight standard with no relation to food solids, other than butterfat, is unjust, for a gallon of water weighs more than a gallon of skim-milk solids, and certainly a gallon of skim-milk solids contains more food value than a gallon of water. If a standard were so drawn as to allow a weight standard for a given percentage of total solids, in addition to the

butterfat standard which we now have, it would require the manufacture of an ice cream containing 33 per cent total solids to obtain a yield of not over 93 per cent, and weighing 4.636 lbs. per gallon—a weight above the standard that is now being advocated. On the other hand, a standard demanding an ice cream with 41 per cent total solids would require a great deal more food value per volume. In other words, a gallon of such ice cream, containing 1.530 lbs. food solids per gallon, would weigh 3.731 lbs. This is far below the weight standard that many have in mind, and until such a time as the weight can be definitely controlled within certain limits, it does not seem desirable to adopt a standard based upon single cans. For this reason, it might be more practical to make use of a standard based on an average of 30 or 40 cans, a certain percentage of which could not be below a certain specified weight per gallon for the percentage of total solids employed by each ice cream manufacturer.

Table LX illustrates three possible standards, the second one being the most desirable.

TABLE LX

Three Possible Standards

| Per Cent T.S. | Weight Mix | Yield, 100% | | OR Food Solids, 1.53 | | OR Wt. per Gal., 4.25 | |
|---|---|---|---|---|---|---|---|
| | | Weight Frozen | Food Solids | Yield | Weight Frozen | Yield | Food Solids |
| 33.0 | 8.95 | 4.475 | 1.476 | 93.0 | 4.636 | 110.5 | 1.402 |
| 36.0 | 8.98 | 4.490 | 1.616 | 111.0 | 4.250 | 111.0 | 1.530 |
| 38.0 | 9.00 | 4.500 | 1.710 | 123.5 | 4.026 | 111.8 | 1.615 |
| 41.0 | 9.04 | 4.520 | 1.853 | 142.3 | 3.731 | 112.4 | 1.742 |
| 46.0 | 9.14 | 4.570 | 2.102 | 174.7 | 3.327 | 115.0 | 1.955 |

No attempt has been made here to recommend a weight standard, but only to show the desirability of tying up a definite percentage of total solids with a weight standard. A weight standard should be accompanied by a sliding scale of varying amounts of total solids.

Table LXI was drawn up with the idea of a weight per gallon, based on varying amounts of total solids, but keeping in mind that the minimum food solids per gallon should be the same in each case. The data represented in this table include a little over 2000 gals. of ice cream.

TABLE LXI

EFFECT OF TOTAL SOLIDS ON DENSITY CONTROL

| Per Cent T.S. | Food Solids per Gallon | Weight per Gallon of Ice Cream | Yield Per Cent | Per Cent of Gallonage below 1.530 Pounds of Food Solids | | | |
|---|---|---|---|---|---|---|---|
| | | | | 1st Can | 2nd Can | 3rd Can | 4th Can |
| 33.8* | 1.530 | 4.527 | 97.9 | 56.2 | 87.5 | 56.2 | 42.85 |
| 36.0 | 1.530 | 4.250 | 106.5 | 0 | 60.0 | 40.0 | 75.0 |
| 38.0 | 1.530 | 4.026 | 123.5 | 0 | 20.0 | 20.0 | 40.0 |
| 41.0 | 1.530 | 3.731 | 142.3 | 0 | 0 | 0 | 0 |
| 46.0 | 1.530 | 3.327 | 174.7 | 0 | 0 | 0 | 0 |

* The weighing type of overrun tester was the only one available at the time these data were gathered.

It will be noted that where 41 per cent total solids were employed, a weight of 3.731 per gallon was required in order to deliver the 1.530 lbs. of food solids per gallon. It was found possible to deliver all of the cans above this standard and still maintain constant food solids per gallon.

**Calculation of the Yield.**—Every plant has, or should have, a record containing such information as the number of runs made each day, the flavor, particular mix used, and gallons frozen. The history should be complete and accurate. It is the policy in many plants to number the batches, beginning on January 1 with No. 1, and continuing throughout the year. In case two or more are made on any one day, letters are made use of, as 1**a**, 1**b**, 1**c**, etc.

The usual method of calculating yield is to subtract the gallons of mix placed in the freezer (including fruit or other flavoring materials) from the gallons of ice cream obtained and divide this difference by the gallons of mix used. In other words, the yield should be based on total gallons added to the freezer. In actual practice, vanilla and color are added in such small amounts that they are not included. To illustrate:

Let $M$ = Gallons of mix in freezer (for practical purposes a gallon of mix weighs 9.0 lbs.)

$Y$ = Gallons of ice cream obtained.

$G$ = Gallons of increase ($G = Y - M$)

$$\frac{G}{M} \times 100 = X \text{ (per cent yield).}$$

If 45 lbs. of mix are put into the freezer, and if a gallon weighs 9 lbs., then 5 gals. of mix is the equivalent of 45 lbs. Assuming that $9\frac{3}{4}$ gals. of vanilla ice cream are obtained, the yield would be calculated as follows:

$$M = 5$$

$$Y = 9\tfrac{3}{4}$$

$$G = 4\tfrac{3}{4}$$

$$X = \frac{4.75}{5} \times 100, \text{ or 95 per cent yield.}$$

Yield can just as well be calculated on weight basis if the information is available. Assuming that a gallon of mix weights 9 lbs. (depending upon the composition, only slight variations of the weight are possible) and the ice cream weighs 4.6 lbs. to the gallon, then $(9.0 - 4.6 = 4.4)$ $\frac{4.4}{4.6} \times 100 = 95.6 +$ per cent.

**Plant Yield.**—The freezer operator often has instructions to obtain a certain yield, occasionally within impossible limits. The tendency in such cases may be to record a yield that is satisfactory, regardless of the actual yield. A monthly plant yield provides a positive check on all operations. It is obtained by determining the gallons of mix made, based on actual purchases, and the gallons of ice cream sold, the gallons of mix and the ice cream on hand at the figuring and at the close of the month being taken into account. The method of calculation is the same as for individual runs.

**Preparing Cans for Hardening.**—As soon as the pre-chilled cans are filled, they should be covered or capped with parchment paper and put into the hardening room. Old rusty cans should be discarded, retinned, or lined. Very satisfactory results are claimed by some manufacturers through the use of can liners. The cans are easy to wash after the liner is removed. If the freshly filled cans are not placed in the cold box at once, the cream softens (especially around the outside), and large ice crystals result upon hardening. The cans should be handled carefully. Pronounced jarring will cause the cream to settle, decreasing the volume in the can. This gives a rough body to the ice cream because of the migration of air cells. Where the hopper system is used, conveyors bring the cans to the filling spout and carry them, when full, into the hardening room. Such a plan is ideal and economical for plants of considerable size.

**Hardening Ice Cream.**—The construction and temperature of the hardening room are discussed in Chapter XI.

The purpose of the hardening room is to complete the freezing of the water in the ice cream. The temperatures used, and hence the rate of freezing, will influence the texture of the ice cream. It has been stated that a little less than 50 per cent of the free moisture is frozen in the freezer. The process is completed in the hardening room. The freezing point of ice cream (as has been previously shown) depends upon the total number of molecules of solid matter in true solution. For this reason, no definite temperature for hardening can be given. The principle underlying the proper method and time of hardening is easy to determine when the theory of crystallization is understood.

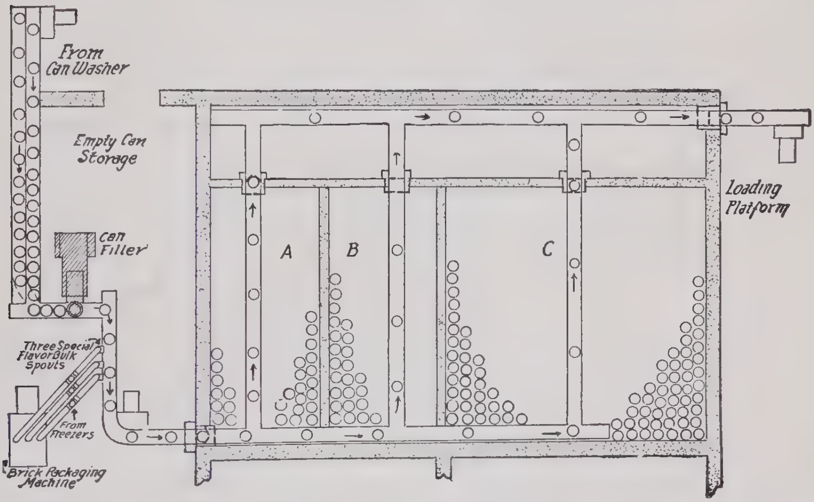



Fig. 65.—Hardening Room with Continuous Conveyor System. After Being Filled, the Cans are Conveyed into One of the Three Hardening Room Sections *A*, *B*, and *C*, and after Hardening for the Proper Period they are Conveyed Directly Out to the Loading Platform.

Hallimond,[28] Ostwald,[29] and Miers and Isaacs[30] have shown that the supercooling of a solution has the tendency to form crystals rapidly with each decrease in temperature, but that, as the temperature continues to decrease, the tendency diminishes so that it is possible to cause the material to become an amorphous mass. With modern methods of cooling, nuclei may even fail to appear. Ostwald has termed this condition "meta-stable." When the conditions are changed so that they appear, he calls it "labile." Hallimond says there are three fundamental principles involved in the theory of crystallization. The first is known

[28] Hallimond, A. F., Jour. Iron and Steel Inst., Vol. 105, No. 1, p. 359, 1922.

[29] Ostwald, W., Zeitschr. f. physikal. Chem., Bd. 22, S. 289, 1897.

[30] Miers, H. A., and Isaacs, F., Jour. Chem. Soc. London, Vol. 89, p. 413, 1906.

as the ordinary solubility curve, which each constituent has within certain temperatures and concentrations, crystallization being brought about by the addition of suitable nuclei. The second is the effect of supercooling on the rate of crystal growth; and the third is the changing of temperatures and the migration of dissolved matter essential to solidification at the surface of the growing crystal, the governing influence being the temperature and concentration.

In ice cream, a considerable portion of the water is tied up or fixed with the serum. This fixation is not stable enough to withstand severe shocks. It is known that a certain amount of water must be frozen *in situ* in the hardening room. The crystallization theory, therefore, may be applied by beginning the freezing process as soon as possible after the ice cream is drawn, and completing the cooling in as short a time as possible. A temperature of 0° F. or less should be maintained in the hardening room, and, whatever it may be, it should fluctuate as little as possible. A storage temperature of $-10°$ F. is considered none too cold. "Shocking" the cream by sudden changes in temperature is conducive to crystal growth (water and sugar). If the water is frozen quickly enough, smaller crystals result and a smoother ice cream is obtained.

**Brick Ice Cream.**—The tendency to manufacture and sell packaged goods has led to the development of great efficiency in the packaging of many foods, and is influencing the marketing of ice cream. The first form of packaged goods was the ice cream brick, which is now made in several shapes, the two most common being the eastern or short brick and the western or long brick. Brick ice cream is usually put up in pint and quart sizes. These are made by filling moulds or slabs, usually of 1 and 2-gal. capacities; after hardening, they are cut into the sizes desired. These moulds for the most part are filled directly from the freezer, in one, two, or three-flavor layers. They are also filled by pouring soft cream from cans. There are special machines for filling the cartons directly.

When slabs are filled, it is necessary to harden, then take out of the pan, and cut up into the desired quantities (quarts, pints, or individual slices), which are then wrapped and cartoned. This method necessitates several steps. When the filling machine is used, the soft cream from the freezer is placed in the hopper, and thence in the carton, which has been previously lined. The cream is hardened in the carton.

Judkins[31] shows a number of determinations comparing machine-filled bricks with slab-filled bricks.

[31] Judkins, H. F., A survey of factors involved in the manufacture and sale of ice cream. Ice Cream Review, May, 1926, p. 106.

TABLE LXII

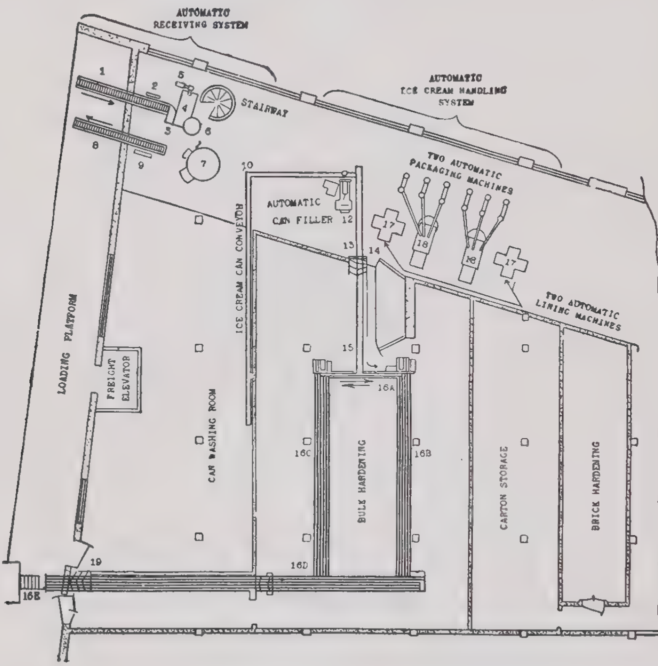
COMPARISON BETWEEN MACHINE-FILLED AND SLAB-FILLED BRICKS

| Mfr. | Number of Bricks | | Average Weight, Ounces | | Greatest Variation, Ounces | | Percentage of Total Having Same Weight | | Average per Cent Yield | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Machine-filled | Slab-filled | Machine-filled | Slab-filled | Machine-filled | Slab-filled | Machine-filled | Slab-filled | Machine-filled | Slab-filled |
| G | 25 | | 9.36 | | .33 | | 84 | | 92 | |
| A | 27 | | 10.45 | | 1.6 | | 55.5 | | 72.2 | |
| H | | 27 | | 9.37 | | 2.5 | | 18.51 | | 96.3 |
| F | | 20 | | 8.98 | | 1.75 | | 25.00 | | 100.0 |
| E | | 24 | | 9.00 | | 2.25 | | 25.00 | | 100.0 |
| C | | 24 | | 9.36 | | 1.75 | | 25.00 | | 96.5 |
| P | | 10 | | 8.94 | | 1.75 | | 30.00 | | 103.5 |

The average weight of the 157 bricks was 9.36 oz. Those cut from slabs vary about twice as much in weight as those filled by machine. This is probably due to careless filling, bent pans, and careless cutting. The average yield for the brick cream in the table above was 94.3 per cent, very close to the average yield of bulk ice cream, and yet too high for the production of good brick ice cream, if made from a mix containing 36 to 37 per cent total solids. In Plants G and A, the same kind of filling machine was used. In G the yield was 20 per cent higher than in A, though G had the least variation (0.33 oz. per quart) and 84 per cent of G's bricks weighed the same. The fact that G's mix contained 2 per cent more total solids aided in stabilizing the cream and thus hindered rapid changes in air content, enabling better operating methods. Thirty-one pint bricks purchased from dealers representing 23 manufacturers varied in weight from 7 oz. to 15.25 oz., or over 100 per cent variation in the cut of a pint brick. This is one of the reasons that brick ice cream is not more popular as a "carry-out" package.

**Hopper System.**—In new plants, the hopper system is being installed. This system meets with considerable success as an economical method of filling cans, and is an aid in controlling the weight per gallon or the density of ice cream. There is a marked change in the percentage of yield during the unloading process. The longer the time required to unload, the greater the change. Hence, 1-gal. cans vary more than 5-gal. ones, and bricks vary more than bulk. This applies to containers filled at the freezer. When cans are filled at the freezer it requires 60–140 seconds to empty an 80-qt. freezer, and 50–100 seconds for a 40-qt. freezer, depending upon how well the freezer is drained. The first can requires 5–10 seconds to fill, while the last may require 20–80 seconds

or longer, depending again on how well the freezer is drained. When hoppers are used, the freezer may be opened wide and left open; the emptying process is, of course, faster. Freezers should not be allowed to drain too long. If too much time be allowed the draining, icy, coarse cream, which is much too heavy for good quality, is produced. This applies to the hopper system as well. Experience has shown that very little change takes place in the density of the ice cream while it is in the hopper and

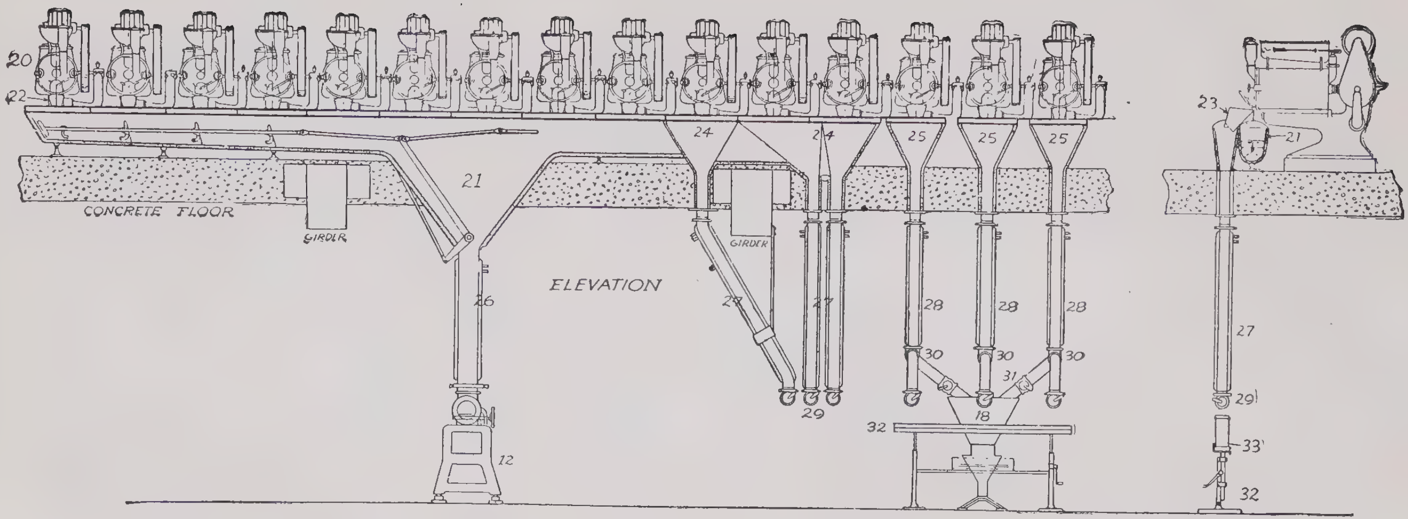



*Courtesy Ice Cream Trade Journal*

FIG. 66.—The material Handling System for the Hydrox Plant.

(1) Can conveyor; (2) automatic scale; (3) can dump; (4) receiving truck; (5) milk pump; (6) automatic drip saver; (7) can washer; (8) can conveyor; (9) automatic empty can scale; (10) ice cream can conveyor; (11) can conveyor power unit; (12) Mojonnier automatic can filler; (13) can counter; (14) automatic self-closing doors; (15) 2-chain filled can conveyor; (16*A*) reversible conveyor, (16*B* and *C*) 6-chain 2-can conveyor; (16*D*) 6-chain actuated conveyor to loading platform; (16*E*) roller conveyor to trucks; (17) brick carton lining machine; (18) brick packaging machines; (19) self closing door.

filling pipe. Of course, the pipe should be insulated and refrigerated, and the cream should never be left standing in the pipe, for the same migration of air cells observed with the 5-gal. can will take place. The hopper system is made with and without conveyors, which move the mix toward the pipe. It is questionable just which type is the more desirable. Either type is better than none at all.




*Courtesy Ice Cream Trade Journal*

Fig. 67.—Cross-section of Freezer Room of Hydrox Plant.

(20) Battery of 100-quart freezers; (21) hopper; (22) funnels to hopper; (23) by-pass funnel; (24–25) individual hoppers; (26–27–28) tubes leading to packaging machines; (29–30–31) discharge valves; (32) adjustment table for filling cans; (33) ice cream can on adjustment table.

In the survey, Judkins[32] found the average difference in weight in 5-gal. cans to be as follows: Hopper system, 2.27 lbs.; drawing directly into cans, 2.62 lbs. In every instance weight control was closer with the hopper system.

**Delivery.**—Many articles have been written in the journals on icing, delivery, depreciation costs, etc. This important phase of the industry requires a separate volume and will not be treated here. Suffice it to say that this so-called service is one of the much-abused phases of the industry. The furnishing of cabinets and equipment has reached such a point in some sections that it is almost possible to start a soda fountain with a capital of one white apron.

Iceless cabinets are making radical changes in the methods of delivery. It is rapidly becoming unnecessary for trucks to have special compartments for salt and ice in service cabinets. The modern truck is refrigerated by a self-contained automatic unit and carries nothing but ice cream in its containers.

**Dipping Shrinkage.**—The manufacturer should consider the dealer his agent. He should be just as interested in his product from the time it leaves his plant until it is consumed as he was in its preparation. The mere placing of the cream in the dealer's cabinets does not relieve the manufacturer of his responsibility. This is particularly the case when the dealer associates the name of the manufacturer with the product he is selling. The dealer must be furnished with a product that can be dispensed properly and economically. Much has been written about dippage losses, and the conditions are frequently exaggerated. As long as bulk ice cream is sold, so long will there be a difference between the volume the dealer buys and the volume he sells. Accordingly, a price differential has been established to compensate for a reasonable decrease in volume. If the dealer actually sold the same volume that he purchased, he would be making far too great a profit, as the prices now range. A certain amount of air is just as necessary to make ice cream palatable as it is to make bread palatable. The air is used in bread to increase the yield, as it is in ice cream.

Excessive dippage losses are often credited to the manufacturer, when in reality the temperature at which the cream is dipped, or the person doing the dipping, is at fault. Most authorities accept 90–100 per cent yield on a 36 per cent solids basis as not excessive. If this be so, under good dipping conditions, a shrinkage of approximately 30 per cent may be expected. In other words, the dealer can expect to sell only about 3.5 gals. out of a 5-gal. can of vanilla, if it is dipped into

[32] Judkins, H. F., A survey of the factors involved in the manufacture and sale of ice cream. Ice Cream Review, April and May, 1926.

quart containers. If it is dipped into pints, he will sell even less. If the yield is decreased and the percentage of solids maintained, it will be possible to dip as much as 4.0 gals. out of every 5; but in such an instance the manufacturer undoubtedly would have to have more per gallon for his cream. As a result, the consumer would be receiving a soggy cream and the dealer making no more. This discussion may appear to be in defense of high yield, but such is not the case. Too much yield is more damaging to the industry than not enough. The aim is solely to produce a perfect ice cream. The consumer is entitled to a definite amount of food solids per gallon, and, if necessary, legislation should protect him.

Assuming that the dealer pays $6.00 for a 5-gal. can of vanilla ice cream and sells 14 qts. (3.5 gals.) from it, at 60 cents a quart he would receive $10.50, or a gross 75 per cent. It is not unreasonable to believe such a return possible and adequate. Unfortunately, it must be admitted that, because of many factors, this return is not usually obtained. The following table [33] is given to illustrate the effect on sales with five different operators dipping, all other factors being constant.

TABLE LXIII

EFFECT OF OPERATOR ON SALES

| Operator | Yield, Per Cent | Average Weight in Ounces of Pint Container |
|---|---|---|
| 1 | 125 | 10.1 |
| 2 | 125 | 11.0 |
| 3 | 125 | 12.4 |
| 4 | 125 | 10.8 |
| 5 | 125 | 14.5 |

It can readily be seen that the returns from ice cream dipped by No. 1 and No. 5 would be considerably different. On a basis of No. 5's work, No. 1 dipped 30.4 per cent less. These data were collected with ice cream containing too much air in relation to the total solids (approximately 36 per cent being used).

If the yield is increased, the solids should be increased in sufficient percentage to maintain a uniform amount of food solids to the gallon.

In the case of lower yield, a careless operator will do less damage, as demonstrated by Phillips in the following table, the same operators being used as in table LXIII.

[33] Phillips, W. A., Mass. Agr. College. Unpublished data.

TABLE LXIV

EFFECT OF OPERATOR ON SALES

| Operator | Yield, Per Cent | Average Weight in Ounces of Pint Containers |
|---|---|---|
| 1 | 95 | 11.9 |
| 2 | 95 | 11.5 |
| 3 | 95 | 14.1 |
| 4 | 85 | 12.6 |
| 5 | 90 | 13.1 |

No. 5, in the first table, succeeded in packing more into the carton. In Table LXIV, No. 5, after deducting the difference in the percentage of yield, came close to his previous performance. No. 1 obtained fairly uniform results, after allowance is made for the difference in the yield of the two creams.

**Temperature of Dipping.**—As already stated, the temperature at which the cream is dipped has much to do with the volume dipped.

Bierman[34] says that there is a temperature which causes the greatest shrinkage during dipping, and that above and below that temperature less shrinkage will be experienced. He presents the following table:

TABLE LXV

EFFECT OF TEMPERATURE ON SHRINKAGE

| Dipping Temperature, ° F. | Average Per Cent Yield | Ounces per Quart before Dipping | Ounces per Quart after Dipping |
|---|---|---|---|
| 3 to 8 | 90 | 19.34 | 25.72 |
| 9 to 16 | 90 | 19.34 | 26.82 |
| 17 to 20 | 90 | 19.34 | 24.46 |

From the difference in shrinkage with the range of temperatures given, it will be seen that the colder temperature (3–8° F.) causes less loss. The correct dipping temperature must vary because of differences in composition of the mix, amount of air the cream contains, and the class of help doing the dipping. Ice cream dipped at cold temperature (where possible) may be desirable for carry-out pails, but that con-

[34] Bierman, H. R., Effect of temperature on dipping. Ice Cream Review, Aug., 1926.

sumed at the fountain is not palatable when served so hard. The practice of service ice cream at the proper temperature for eating is a factor in increasing consumption. In the following table, the results simulate those shown in the preceding table except that the smallest percentage of shrinkage was obtained at the higher temperature. The medium temperature—the one at which ice cream is usually dipped—is the least desirable, considering shrinkage as the only factor.

TABLE LXVI

EFFECT OF TEMPERATURE ON SHRINKAGE

| Dishing Temperature, ° F. | Number of 3-gal. Cans | Net Weight, Pounds | Yield, Per Cent | Number of Pints | Net Weight of Pts., Oz. | Volume Per Cent Shrinkage |
|---|---|---|---|---|---|---|
| 5 | 3 | 14.0 | 92 | 17.1 | 13.0 | 29 |
| 10 | 8 | 13.9 | 96 | 16.5 | 13.0 | 30 |
| 15 | 3 | 13.8 | 96 | 16.6 | 13.1 | 31 |
| 23* | 1 | 13.7 | 96 | 20.0 | 9.88 | 17 |

* Too soft to be practical and not enough cans to draw conclusions.

The variation in shrinkage due to temperature changes, from 3° to 23° F., may be kept between 6 and 10 per cent. Varying the percentage of yield, with the solids remaining constant, will give a varying percentage of shrinkage. The following table [35] shows that increasing the yield, all other factors remaining constant, increases the shrinkage.

TABLE LXVII

EFFECT OF YIELD ON SHRINKAGE

| Series | Average Yield, Per Cent | Dippage from 20 Quarts | Per Cent Shrinkage |
|---|---|---|---|
| 1 | 60.3 | 16.96 | 15.18 |
| 2 | 80.6 | 15.37 | 23.14 |
| 3 | 100.8 | 14.07 | 29.66 |
| 4 | 118.6 | 31.45 | 32.76 |
| Average | 90.1 | 14.96 | 25.18 |

It will be noted that there is a difference of 20 per cent in yield between Series 1 and 2, while the difference in the shrinkage is 8 per

[35] Bierman, H. R., and Bromley, W. A., Effect of overrun on dipping. Ice Cream Review, July, 1926.

TABLE LXVIII

SHOWING DATA ON PINTS OF ICE CREAM PURCHASED FROM DIFFERENT DEALERS TOGETHER WITH PROFITS, ASSUMING ALL ICE CREAM SOLD IN THIS MANNER

| Number of Mfr. | Number of Dealers | Average Weight of 1 Pint, Ounces | Quart Weight of 1 Pint, Ounces | Average Weight of 5 Gallons, Pounds | Quarts Calculated per 5 Gallons, Dipped | Rec. from 5 Gallons at 60 Cents per Quart | Mfr. Price per Gallon | Cost of 5 Gallons | Gross Profit per 5 Gallons | Gross Profit Per Cent of Cost | Gross Profit Per Cent of Repts. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 6 | 14.37 | 28.74 | 26.28 | 14.7 | 8.82 | 1.40 | 7.00 | 1.82 | 25.71 | 20.6 |
| B | 5 | 14.02 | 28.04 | 23.25 | 13.26 | 7.96 | 1.35 | 6.75 | 1.21 | 17.92 | 15.2 |
| C | 8 | 14.05 | 28.10 | 21.8 | 12.41 | 7.45 | 1.35 | 6.75 | .70 | 10.37 | 9.4 |
| D | 8 | 14.58 | 29.16 | 23.3 | 12.78 | 7.67 | 1.30 | 6.50 | 1.17 | 18.0 | 15.2 |
| E | 5 | 13.43 | 26.86 | 22.78 | 13.57 | 8.14 | 1.35 | 6.75 | 1.39 | 20.59 | 17.0 |
| F | 6 | 13.31 | 26.62 | 21.19 | 12.73 | 7.64 | 1.30 | 6.50 | 1.14 | 17.63 | 14.9 |
| G | 5 | 13.69 | 27.38 | 22.68 | 13.25 | 7.95 | 1.30 | 6.50 | 1.45 | 22.3 | 18.2 |
| H | 6 | 14.65 | 29.30 | 22.58 | 12.32 | 7.39 | 1.30 | 6.50 | .85 | 13.07 | 11.5 |
| I | 7 | 15.9 | 31.8 | 22.7 | 11.42 | 6.85 | 1.30 | 6.50 | .35 | 5.38 | 5.1 |
| Total.... | 56 | 128.00 | 256.00 | 206.56 | 116.44 | 69.87 | 11.95 | 59.75 | 10.08 | 150.87 | 126.56 |
| Average.. | ....... | 14.22 | 28.44 | 22.95 | 12.93 | 7.76 | 1.33 | 6.64 | 1.12 | 16.8 | 14.7 |

cent. The difference in yield between 2 and 3 is 20 per cent, and in shrinkage, 6.5 per cent. The same thing holds true for 3 and 4, which also have a difference of practically 20 per cent in yield and only 3 per cent in shrinkage. If the food solids per gallon had been increased accordingly, the results would have been different. The variation in yield, as ice cream has been manufactured, probably causes the dealer's shrinkage to vary unduly from 8 to 15 per cent.

The work discussed so far under this subject has been done largely in laboratories. The results show uniformly less dipping loss than Judkins[36] actually found in data gathered in New England under commercial conditions.

In Table LXVIII it is interesting to note that some of the dealers sold pints weighing slightly in excess of 11 oz., while others sold pints weighing as much as 20 oz. Out of the 56 pints purchased, 34, or 60.7 per cent, weighed between 13.01 and 15.0 oz., there being comparatively little uniformity in the quantity put into the carton. It is also interesting to note that while manufacturer A sold his ice cream for more per gallon, his dealer made a larger gross profit. This manufacturer's ice cream was much heavier (5.25 lbs. to the gallon) and the price differential of 5 cents per gallon would not justify this decreased yield unless a low percentage of total solids were used. This particular mix, however, contained 14 per cent fat, 15.4 per cent sugar, and 39.0 per cent total solids.

The size of the disher or scoop apparently has no effect upon the dippage loss per gallon.

TABLE LXIX

EFFECT OF SIZE DISHER ON LOSS PER GALLON

| Size of Disher | Number of Cans Dipped | Net Weight in Pounds, 3 Gallons | Yield Per Cent | Dishersful | | Equivalent | | Volume Per Cent Shrinkage |
|---|---|---|---|---|---|---|---|---|
| | | | | Number | Average weight per scoop, grams | Quarts dipped from 3-gallon can | Scoops from a quart | |
| 10 | 4 | 13.7 | 97 | 70 | 3.1 | 7.0 | 5.8 | 42 |
| 12 | 12 | 14.0 | 99 | 81 | 2.6 | 6.9 | 5.9 | 44 |
| 16 | 4 | 14.2 | 93 | 117 | 1.9 | 7.4 | 9.8 | 36 |
| 20 | 3 | 14.0 | 93 | 131 | 1.7 | 6.8 | 10.9 | 44 |
| 24 | 6 | 14.1 | 97 | 170 | 1.3 | 7.0 | 14.1 | 41 |
| 30 | 3 | 13.9 | 98 | 209 | 1.0 | 6.9 | 17.1 | 42 |

[36] Judkins, H. F., A survey of factors involved in the manufacture and sale of ice cream. Ice Cream Review, May, 1926, p. 106.

It would appear from Table LXIX[37] that the operator, not the scoop, is the important factor in controlling shrinkage. Three tables have been presented here to show the wide variation in shrinkage obtained by three investigators. In Table LXVII, the average shrinkage was 25.18 per cent for some 1200 gals. In Table LXVIII, where samples were gathered on the market, the average shrinkage was 35.0 per cent, and in Table LXIX it was 41.5 per cent. The spread seems to be entirely too wide. It is also noted that the average yield in Table LXIX was 96 per cent, while in Table LXVII it went as high as 118.6 per cent.

**Type of Scoop.**—Authorities do not agree as to the type of scoop that is most desirable for filling cartons. It is injurious to the quality of the ice cream to jam it into a carton. Such a practice also causes excessive shrinkage. Some work has been done indicating that the shrinkage can be reduced 8–10 per cent by using a transfer ladle. Judkins, in his survey found that out of 168 pints purchased, 27 were dipped with a scoop and averaged 0.53 oz., or a little over 1 oz. to the quart, lighter than those dipped with the ladle. This is equivalent to a loss of slightly more than $\frac{1}{4}$ lb. to the gallon. These figures are cited to impress upon the reader the importance of a small detail in increasing the gross returns. Probably, because of migration of air cells, the bottoms of 5-gal. containers invariably are heavier per gallon, the bottom half containing 6–17 oz. more than the top half. The higher the solids in the mix, the less likely is this to be true.

TABLE LXX

Dealer's Profit on Carry-out and Scoop Business

| | Gross on Purchase, Per Cent | Gross on Sales, Per Cent |
|---|---|---|
| 100 per cent carry-out business.... | 19 | 16 |
| 75 per cent carry-out business<br>25 per cent scoop business....... | 40 | 28 |
| 50 per cent carry-out business<br>50 per cent scoop business....... | 63 | 39 |
| 25 per cent carry-out business<br>75 per cent scoop business....... | 86 | 46 |
| 100 per cent scoop business....... | 109 | 52 |

[37] Phillips, W. A., Mass. Agr. College. Unpublished data.

Increased consumption depends to some extent upon the increased consumption in the home. This means that attention must be given to the carry-out business, which many dealers regard as unprofitable. Undoubtedly, as it is now carried on, it is the least profitable part of the business. Table LXX, summarizing this phase of Judkins' survey, is here presented. These data are compiled from actual commercial transactions in which ice cream in bulk cost $1.30 per gallon and sold for 60 cents per quart and for 10 cents per No. 10 scoop.

In some instances, even under present methods of doing business, the returns are too high over the fountain, while in a strictly carry-out business they are too low. The manufacturers realize this and know that before home consumption can be increased to any extent, remedies must be found. The remedy may be a better quality of ice cream brick, i.e., lower yield, or it may be supervision and skill at the fountain.

# CHAPTER VIII

## BACTERIA IN ICE CREAM

Circumstances are forcing the ice cream manufacturer to a consideration of bacteria. Until recently, ice cream was not thought of as containing bacteria, because of a mistaken idea that cold has a bactericidal effect. The work of health officials in scoring milk and publishing the results along with the bacterial count, and the educational work of the dairy councils and universities, have led the public to associate quality in dairy products with a low bacterial count. It is quite natural that the same feeling should exist for ice cream.

The present consideration of the food value of ice cream, its healthfulness for invalids, and the growth-promoting qualities it furnishes children have had the effect of turning the public spotlight on this product. If the manufacturer is to capitalize on this publicity, his product must be beyond reproach from a bacteriological standpoint.

The last link in this chain of circumstances will be, it is believed, state and Federal legislation establishing a bacteriological standard for ice cream. Most states have well-defined regulations governing the chemical composition, but there is a conspicuous lack of bacteriological standards. Unfavorable publicity has been given the industry from time to time when certain epidemics have been traced to ice cream.[1] Legislation has usually resulted from this publicity.

**Bacteriological Standard.**—At the end of 1926, only four states, Arkansas, Iowa, Louisiana, and Tennessee, have laws requiring the pasteurization of the ice cream mix, while four others require the pasteurization of the dairy products going into the mix. In California all ingredients which do not come from sources that are tuberculosis-free must be pasteurized. This means that most of the mix is pasteurized, since a large amount of some kind of condensed milk is used, and it is impracticable to secure this from tuberculosis-free sources.

Just what the bacteriological standard for ice cream will be is difficult to predict. Probably it will vary in the different states just as the

[1] Fabian, F. W., Ice cream as a cause of epidemics. American Journal of Public Health, Vol. XVI, No. 9, p. 873.

butterfat standard for ice cream and the bacteriological standard for milk do to-day.

Olson and Fay,[2] in work done on ice cream in Kansas, found that pasteurization at 145° F. for thirty minutes and homogenization at pasteurization temperature result in bacterial counts (plate method) of less than 100,000 per gram in the finished ice cream. They conclude that it is practicable under plant conditions to produce ice cream with less than this number. Since the manufacturer should know the source of bacteria in ice cream and how to produce a product with a low count, this chapter will treat the subject from two pertinent angles; namely, raw materials as a source of bacteria, and the bacteriological effect of processing.

**Raw Materials as a Source of Contamination.**—The ingredients used in the mix naturally constitute the principal source of bacteria.

*Water*, of which the mix contains the largest percentage, is seldom a source of contamination. Boards of health usually give careful supervision to the city water supply. The greatest danger from this source has been found in the small country plants where community sanitation is not strictly enforced.

*Milk and Cream* in the mix have been proved by Olson and Fay[3] to be responsible in most instances for over 99 per cent of the bacteria that are present before pasteurization.

It is not unusual to find many million bacteria per cubic centimeter in cream. When such a product goes into the mix, even a pasteurizing efficiency of 99 per cent cannot produce ice cream that has a low count. There is only one remedy for this situation; namely, to purchase milk and cream of a better quality. It is axiomatic that good raw materials are necessary to produce a good finished product.

*The various kinds of condensed milk* should not add, proportionately, as many bacteria as milk and cream. Hunziker[4] states that "plain condensed bulk milk when fresh contains from about 1000 to 100,000 bacteria per c.c.; when several days old and in the absence of refrigeration, its germ content is often much greater. Sweetened condensed milk averages from about 500 to 500,000 bacteria per c.c."

*Condensed skim milk*, however, may have a very high bacterial count. Olson and Fay found that in one case condensed milk supplied 56 per cent of the total number of organisms in the unpasteurized mix, while

[2] Olson, N. E., and Fay, A. C., Bacterial content of ice cream. Journal of Dairy Science, Vol. VII, p. 354.

[3] Olson, N. E., and Fay, A. C., Bacterial content of ice cream, Journal of Dairy Science, Vol. VII, p. 354.

[4] Hunziker, O. F., Condensed Milk and Milk Powder, p. 375.

in another, it was responsible for only 0.04 per cent. The quality of condensed milk, therefore, should be carefully guarded.

*Dry milk powder*, as it comes from the manufacturer, contains comparatively few organisms. The best grades of skim-milk powder are so low in bacteria as to exert a negligible influence on the count of the finished product. Subsequent contamination in the ice cream plant is usually the case, particularly if the powder is exposed to air and dust.

Tests extending over two months have shown[5] that powdered skim milk, shipped from New Zealand to England and then repacked, had only a maximum count of 3392 bacteria per cubic centimeter, with an average for the period of 213 per cubic centimeter.

*Sugar* is seldom a source of contamination, if it is kept dry and free from dust.

*Gelatin*, as shown by experimental work, is a much better product than it was a few years ago. In 1912, Hammer[6] found that the count of 5 gelatin samples varied from 35 to 113,000,000 bacteria per gram. In 1923, Parfitt,[7] analyzing 17 samples, got a variation of from 100 to 60,000,000 per gram.

To determine the bacteriological condition of gelatin found on the market for 1923–24, Brannon and Tracy[8] collected 37 samples from ice cream manufacturers. They found that only 5 had counts of more than 1,000,000 per gram, while 3 were sterile, and 21 had counts between 100 and 10,000.

It is evident, therefore, that gelatin manufacturers can produce a product with a low count. Brannon and Tracy proved further, however, that the bacterial content of the same brand of gelatin may have large variations. *Caveat emptor.* They have also shown that an unwashed gelatin kettle may be a source of contamination.

It is not likely that the bacterial count of gelatin will increase to any extent after it leaves the manufacturer, unless, of course, it is contaminated from outside sources or becomes damp.

The temperature to which gelatin is heated in order to liquefy it exerts a strong influence on the number of bacteria which it carries to the mix. Ellenberger[9] dissolved 15 samples of gelatin at a temperature

[5] Jephcott, H., Heinwick, R. F., and Ratcliffe, N., before World's Dairy Congress, 1923.

[6] Hammer, B. W., Iowa Agr. Exp. Sta. Bul. 134.

[7] Parfitt, E. H., study of gelatin for the manufacture of ice cream. Ice Cream Review, Vol. VII, 58.

[8] Brannon, S. M., and Tracy, P. H., Gelatin as a source of bacteria in ice cream. Journal of Dairy Science, Vol. VIII, p. 115.

[9] Ellenberger, H. B., A study of bacteria in ice cream during storage. Memoir 18, Cornell University Agr. Exp. Sta.

of 125–130° F. and got an average total count of 388,162; at 160–170° F., the average was 1172. When the gelatin dissolved in boiling water, the average count was only 530.

TABLE LXXI

TEST TO DETERMINE THE EFFECT OF HEAT ON THE BACTERIAL COUNT AND GELLING STRENGTH *

| Sample Number | Temperature Put into Solution | Bacterial Count | Time Required to Assume Liquid State at 45° C. after Setting 48 Hours |
|---|---|---|---|
| 1 | 50° C. | 11,000 | 15½ Minutes |
| 2 | 75° C. | 300 | 16 Minutes |
| 3 | 100° C. | 200 | 13 Minutes |
| 4 | 125° C. | Sterile | 14 Minutes |
| 5 | 125° C. | Sterile | 12 Minutes |
| 6 | 125° C. | Sterile | 10 Minutes |
| 7 | 50° C. | 90,000 | 17 Minutes |
| 8 | 75° C. | 400 | 14 Minutes |
| 9 | 100° C. | 400 | 17 Minutes |
| 10 | 125° C. | Sterile | 12 Minutes |
| 11 | 125° C. | Sterile | 10 Minutes |
| 12 | 125° C. | Sterile | 8 Minutes |

One gram of gelatin was put into solution in 100 c.c. of water and heated to the temperature above. Samples 1, 2, 3, 4, and 7, 8, 9, 10, were held for 10 minutes at indicated temperatures; samples 5 and 11, for 20 minutes; samples 6 and 12, for 30 minutes.

* From unpublished work of G. D. Turnbow, Agr. Exp. Sta., University of California

NOTE. Temperatures of 75 and 100° C. seem to kill all but the heat-resisting bacteria. Steam under pressure killed all the bacteria. (It should be mentioned here that very excellent grades of gelatin were used, hence the apparent ineffectiveness of heat except for long holding periods under pressure.)

*Flavors* may be expected to contain few bacteria if they are of alcoholic extraction. Alcohol has a well-known germicidal action and is sufficiently strong in good extracts to inhibit bacterial growth. Hammer[10] found counts in vanilla extracts ranging from 200 to 2300 per cubic centimeter. The percentage of vanilla that goes into ice cream makes this constituent a negligible factor, in so far as bacteria in the finished product is concerned.

*Cold-pack fruits* and berries, particularly the so-called jumbo pack of the latter, have been known to contain great numbers of bacteria. Berries, in the height of the season, are sometimes packed when covered

[10] Hammer, B. W., Bacteria and ice cream. Iowa Exp. Sta. Bul. 134.

with yeasts and moulds. Although the sugar syrup and the low temperature may retard further growth, great numbers remain in the berries. The average yeast and mould count of strawberries should not exceed 3200 of yeasts and 6800 of moulds per gram.

*Coal-tar dyes* in water solutions are prone to decomposition unless they contain a small amount of some such preservative as benzoate of soda. The California State Department of Agriculture[11] found as many as 93,000,000 bacteria per cubic centimeter in examining colors used in the various plants in that state. They found that there was a tendency on the part of manufacturers to make up too large a stock of aqueous colors. The length of time elapsing before these were used up allowed large numbers of bacteria to develop.

**The Bacteriological Effect of Processing.**—The first change in the bacterial count is noticed in the mix before pasteurization. Adding the various high-count ingredients to the needed amount of water, the latter usually of low bacterial count, will naturally give a lower count in the mix than existed in the cream. Hammer and Sanders[12] found, however, that this decrease is greater than could be normally accounted for by the volume change. The cream count in eight tests was higher than the count on the mix by 8–75 per cent and averaged 43.6 per cent. They believe that the plasmolyzing influence of the sugar added must be largely responsible.

**The Effect of Heating the Mix without Holding.**—Hammer and Sanders, in the work referred to above, found that merely heating the mix to 145° F., but without holding it there, effected a decrease in the bacterial count varying from 91.5 per cent to 99.5 per cent, and averaging 96.4 per cent. This decrease is about what normally might be expected in sweet cream and milk as the result of complete pasteurization. Hammer and Sanders conclude: "It is probable that the efficient destruction of the organisms is due to the large amount of material (sugar particularly) present in solution which exerts a much greater plasmolyzing action than does the material present in solution in cream or milk."

**Pasteurization.**—The value and efficiency of pasteurization have been substantiated by numerous experimental data. Fabian and Cromley[13] have shown that pasteurizing the ice cream mix at 150° F. for thirty minutes lowers the plate count from 94.5 per cent to 99.9 per cent, with an average efficiency of 98.97 per cent.

[11] Frey, J. J., Ice cream, proposed definitions and standards for, Official Proc. of 29th Ann. Conf. of Assoc. of Dairy, Food & Drug Officials of the U. S.

[12] Hammer, B. W., and Sanders, L. R., Iowa Agr. Exp. Sta. Bul. No. 186.

[13] Fabian, F. W., and Cromley, R. H., Mich. Agr. Exp. Sta. Tech. Bul. 60.

Hammer and Sanders[14] found the bacterial reduction of the mix by pasteurization to be very satisfactory. Pasteurization at 142–150° F. for twenty minutes gave them the results tabulated below.

TABLE LXXIII

CHANGES IN BACTERIAL CONTENT DURING PROCESSING

| Run | Mix before Pasteurization | Mix after Pasteurization | Pasteurized Mix through Homogenizer without Pressure | Pasteurized Mix through Homogenizer with Pressure | Pasteurized Mix through Homogenizer with Pressure and then over Cooler |
|---|---|---|---|---|---|
| 1 | 56,000 | 170 | 7,400 | 9,450 | |
| 2 | 720,000* | 1,545 | 2,025 | 4,250 | 6,050 |
| 3 | 189,500 | 370 | 2,020 | 850 | 1,285 |
| 4 | 4,400,000 | 230 | 605 | 235 | |
| 5 | 1,050,000 | 66,000 | 78,000 | 72,000 | 84,000 |
| 6 | 2,600,000 | 6,150 | 12,650 | 6,150 | 6,600 |
| 7 | 1,300,000 | 170 | 490 | 375 | |
| 8 | 150,000 | 225 | 430 | 670 | |
| 9 | 15,300,000 | 10,500 | 20,600 | 8,900 | |

* Cream. Unheated mix not counted.

**Effect of Homogenizing the Mix.**—In continuing their bacteriological study, Hammer and Sanders found that when the mix was run through the homogenizer without pressure, there was an increase in the number of bacteria in all cases. However, all the samples analyzed were from the first mix that passed through, which partially freed the machine of bacteria, thus lessening contamination from this source in material subsequently passing through. When the mix was passed through the homogenizer under pressure, an increase in the number of bacteria was shown in all cases except one. Fay and Olson[15] say that an increase of 26 per cent after homogenizing was shown in their studies of this phase of manufacturing ice cream.

Peterson and Tracy[16] agree with Fay and Olson in attributing the increase in bacteria after homogenizing largely to the breaking up of the clumps of bacteria. In the plate method of counting, these clusters had appeared in the agar as one colony. When they were broken up by the homogenizer, they appeared as a number of colonies. Thus, the increase

[14] Hammer, B. W., and Sanders, L. R., Iowa Agr. Exp. Sta. Bul. 186.

[15] Fay, A. C., and Olson, N. E., The bacterial content of ice cream. Journal of Dairy Science, Vol. VII, 9, pp. 330–356.

[16] Peterson, R. W., and Tracy, P. H., The condensation process of preparing an ice cream mix. Journal of Dairy Science, Vol. V, pp. 273–281.

in bacteria by the plate count after homogenization is more apparent than real.

It should be evident to the manufacturer, however, that the homogenizer may be a source of real contamination. Scrupulous care in cleaning it will be necessary, if the count is to be kept down. Running a solution of washing powder and hot water through it after using will not clean the homogenizing head. The careful manufacturer will take the homogenizer apart after each using and brush those parts that come in contact with the mix. An added precaution is to run hot water through all parts before using. This will tend to flush out the homogenizer and prevent the high contamination of the first mix.

Investigation has shown the tubular cooler also to be a source of bacteria if it has been carelessly washed. This piece of equipment must be just as carefully brushed and cleaned as any other. A mixture of hot water and steam should then be turned on the cooler until the metal is so hot that it will dry quickly.

**Effect of Aging on Bacterial Content.**—The results of the work Fay and Olson[17] show practically no change in the bacterial count before and after aging. Bacterial growth is very slow at the temperature used for this purpose. Fifteen to eighteen hours showed practically no change. Fay and Olson, however, make the following statement:

> When long aging periods are used, a slight increase may be expected, but if the temperature is properly controlled, this increase should not be sufficient to cause an excessively high count in the finished product. However, if the temperature is not well controlled and is allowed to raise only a few degrees, the bacterial content will be greatly increased. Increasing the temperature ten degrees may mean an increase of several hundred per cent in the bacterial count after twenty-four hours.

Hammer and Sanders[18] say the increase in bacteria during aging is caused by insufficient cooling after pasteurization and by holding without stirring. No doubt part of the mix under these conditions remains at a temperature high enough to allow the development of bacteria.

**Effect of Freezer.**—Investigators seem to agree that the mechanical agitation during freezing has the same tendency as homogenization to break up the bacteria clusters. The increased count, therefore, is largely attributed to this mechanical action, and, as in the case of the homogenizer, is more apparent than real. It should be remembered, of course, that the freezer itself is a possible source of contamination.

[17] Fay, A. C., and Olson, N. E., Bacterial content of ice cream. Journal of Dairy Science, Vol. VII, pp. 330–356.

[18] Hammer, B. W., and Sanders, L. R., Iowa Agr. Exp. Sta. Bul. 186.

When properly cleaned, the freezer should not materially increase the number of bacteria. The dasher should always be taken out and brushed. Rinsing, even with the machine running, cannot possibly remove all traces of the mix. When the machine is reassembled, the steam should be allowed to run into the freezing chamber until the metal is hot; so hot, in fact, that when the steam is turned off the heat retained in the metal will thoroughly dry all the moisture in the freezer. Contamination from a freezer so treated is negligible.

It should be unnecessary to mention that the cans should be sterilized with steam before the cream is drawn into them.

**Effect of Hardening.**—Hammer and Sanders[19] made determinations of the bacterial count of 52 samples of ice cream hardened over night, and reached this conclusion:

> It seems, then, that in general the hardening of ice cream results in a decrease in the bacterial content but that the decrease is quite variable in extent, depending presumably on the hardening temperature and the resistance of the contained bacteria to the low temperatures encountered.

Esten and Mason[20] found no marked increase or decrease in the number of bacteria in ice cream stored for about a month.

Pathogenic organisms are not readily killed by freezing temperatures. Ravenel[21] has shown that the viability and virulence of anthrax spores, cultures of *Bacterium diphtheriæ*, *B. typhosus*, and *B. prodigiosus* are apparently not affected by exposure to the temperature of liquid air (312° F. below zero) for periods ranging from fifteen minutes to three hours. Macfadyen[22] and Macfayden and Rowland[23] increased the period of exposure to one week and found that the temperature of liquid air had no material effect on the vitality of the same organisms.

It must be evident to the ice cream manufacturer that control of the number of bacteria in his product requires constant vigilance. Every step in the manufacturing process, except pasteurizing, results in an increase in their number.

While condensing the whole mix is not practiced to a large extent, it should be noted here that heating it in the forewarmer to 160–170° F.,

[19] Hammer, B. W., and Sanders, L. R., Iowa Agr. Exp. Sta. Bul. 174.

[20] Esten, and Mason, Conn. (Storrs) Agr. Exp. Sta. Bul. 83.

[21] Ravenel, M. P., The resistance of bacteria to cold. Med. News, New York, 74:726 (June 10), 1899.

[22] Macfadyen, A., On the influence of the temperature of liquid air on bacteria. Lancet, Mar. 24, 1910, p. 849.

[23] Macfadyen, A., and Rowland, S., Note on the influence of the temperature of liquid air on bacteria. Lancet, Apr. 21, 1900, p. 1130.

and then condensing at a temperature around 130° F., is sufficient to destroy a large percentage of the bacteria. Ayers and Johnson[24] found that this method resulted in an average bacterial destruction of 99.89 per cent.

**Bacteria and Score.**—That there is no apparent correlation between the bacterial count and the flavor in ice cream is evidenced in Table LXXIII. Once a year for three years, a total of sixty-two samples of ice cream from various manufacturers were scored at the Pacific Slope Dairy Show. The score card used was the same as that shown on page 250. Both commercial ice cream manufacturers and technically trained men acted as judges. The table shows that the flavor and texture score of an ice cream has absolutely no relationship to the bacterial count, and leads to a reiteration of the statement that the kind of bacteria, and not the number present, is the all-important factor.

TABLE LXXIII

Bacteria in Ice Cream—Pacific Slope Dairy Show

1924

| Number | Bacterial Count | Flavor Score | Texture Score | Total Score |
|---|---|---|---|---|
| 1 | 25,000 | 41½ | 24 | 95½ |
| 2 | 25,000 | 42 | 24½ | 96½ |
| 3 | 32,500 | 37½ | 25 | 92 |
| 4 | 12,500 | 38½ | 23 | 91½ |
| 5 | 10,000 | 37 | 24½ | 91½ |
| 6 | 75,000 | 37½ | 24 | 90½ |
| 7 | 10,000 | 37 | 25 | 91½ |
| 8 | 12,500 | 42 | 25 | 97 |
| 9 | 30,000 | 37½ | 25 | 92 |
| 10 | 50,000 | 36 | 25 | 90½ |
| 11 | 25,000 | 34 | 25 | 88½ |
| 12 | 10,000 | 35½ | 24 | 89½ |
| 13 | 27,500 | 38 | 24½ | 92½ |
| 14 | 27,500 | 34 | 24½ | 88½ |
| 15 | 45,000 | 37½ | 24 | 91½ |
| 16 | 25,000 | 41¼ | 24½ | 95¾ |
| 17 | 50,000 | 37½ | 25 | 92 |
| 18 | 30,000 | 35 | 25 | 90 |
| 19 | 30,000 | 33 | 24 | 87 |
| 20 | 45,000 | 37½ | 24 | 91½ |
| 21 | 37,000 | 39 | 25 | 94 |
| 22 | 50,000 | 37 | 24½ | 91½ |

[24] Ayers, S. H., and Johnson, W. T., U. S. D. A. Bul. 303.

TABLE LXXIII—*Continued*

1925

| | | | | |
|---|---|---|---|---|
| 1 | 7,000 | 38½ | 23½ | 92 |
| 2 | 14,500 | 37½ | 24 | 91½ |
| 3 | 8,500 | 38 | 23½ | 91½ |
| 4 | 19,000 | 41 | 24¾ | 95¾ |
| 5 | 32,000 | 35 | 23½ | 88½ |
| 6 | 6,500 | 38 | 20 | 87½ |
| 7 | 2,500 | 39 | 24 | 93 |
| 8 | 3,000 | 39½ | 25 | 94½ |
| 9 | 500 | 36½ | 23½ | 89¾ |
| 10 | 25,500 | 35 | 23½ | 88½ |
| 11 | 500 | 40 | 24¾ | 94¾ |
| 12 | 2,000 | 38 | 24 | 91¾ |
| 13 | 3,000 | 40 | 25 | 95 |
| 14 | 838,000 | 35 | 21 | 65¾ |
| 15 | 16,500 | 36½ | 24 | 90 |
| 16 | 7,500 | 37½ | 22 | 89½ |
| 17 | 1,000 | 40¾ | 24¾ | 95½ |
| 18 | 79,000 | 40 | 18 | 86 |

1926

| Number | Bacterial Count | Flavor Score | Texture Score | Total Score |
|---|---|---|---|---|
| 1 | 6,000 | 40 | 24¾ | 94¾ |
| 2 | 2,000 | 37 | 24½ | 91½ |
| 3 | 3,500 | 38½ | 24¾ | 93¼ |
| 4 | 5,500 | 41 | 25 | 96 |
| 5 | 1,000 | 38½ | 24 | 92½ |
| 6 | 5,000 | 38 | 24 | 92 |
| 7 | 1,500 | 36 | 23½ | 89 |
| 8 | 2,500 | 38 | 24 | 92 |
| 9 | 10,500 | 39½ | 25 | 94¼ |
| 10 | 283,000 | 38 | 24½ | 82½ |
| 11 | 5,000 | 37 | 25 | 92 |
| 12 | 17,500 | 38 | 24½ | 92½ |
| 13 | 3,000 | 36 | 24½ | 90½ |
| 14 | 1,500 | 38 | 24½ | 92½ |
| 15 | 8,000 | 37½ | 24½ | 92 |
| 16 | 9,500 | 38 | 24½ | 92½ |
| 17 | 12,000 | 38 | 25 | 93 |
| 18 | 78,000 | 37 | 24½ | 90½ |
| 19 | 10,500 | 38 | 24 | 92 |
| 20 | 6,500 | 38½ | 24¾ | 93¼ |
| 21 | 2,000 | 40 | 25 | 95 |
| 22 | 24,000 | 38 | 24½ | 92½ |

TABLE LXXIV

FACTORY SCORE CARD *

Trade Name........................ Owner or Manager.................

Town or City...................... Business Address..................

Date........................192....

| Equipment | Score | | Methods | Score | |
|---|---|---|---|---|---|
| | Perfect | Allowed | | Perfect | Allowed |
| Building: | | | Building: | | |
| Location: | | | Cleanliness............... | 19 | |
| Free from contaminating surroundings....... | 3 | | Orderly .......... 4 | | |
| | | | Floors............ 3 | | |
| | | | Walls............ 2 | | |
| Arrangements.............. | 7 | | Ceilings.......... 2 | | |
| Proper rooms....... 4 | | | Doors and windows. 2 | | |
| Convenience........ 3 | | | Shafting, pulleys, pipes, etc........ 1 | | |
| Construction............... | 10 | | Freedom from odors. 2 | | |
| Flooring, tight, sound, nonabsorbent..... 4 | | | Freedom from flies.. 3 | | |
| Walls, tight, smooth and cleanable..... 2 | | | Utensils: | | |
| Ceiling, tight, smooth and cleanable..... 2 | | | Cleanliness, vats, homo., etc. | 16 | |
| Minimum of shafting, pulleys, hangers and exposed pipes..... 2 | | | Thoroughly washed and rinsed...... 8 | | |
| | | | Sterilized with live steam (boiling water, 5)....... 8 | | |
| Drainage.................. | 4 | | Brick cutting and hardening room................ | 10 | |
| Floor.............. 2 | | | Cleanliness: | | |
| Sewer or septic tank. 2 | | | Of rooms......... 4 | | |
| Apparatus................. | 12 | | Of stock room..... 2 | | |
| Condition of........ 5 | | | Of packing equipment........... 3 | | |
| Boiler, condition of.. 2 | | | Of moulds........ 1 | | |
| Appliances for cleaning utensils and cans 5 | | | | | |
| Laboratory and equipment.. | 5 | | Machinery................. | 5 | |
| | | | Cleanliness of....... 3 | | |
| Water supply.............. | 2 | | Cleanliness of delivery equipment...... 2 | | |
| Clean and fresh..... 1 | | | | | |
| Convenient and abundant......... 1 | | | Cleanliness of employees..... | 10 | |
| Total.............. | 40 | | Total........... | 60 | |

Score for equipment ............. plus score for methods ............. equals TOTAL SCORE ...............

NOTE. If the conditions in any particular are so exceptionally bad as to be inadequately expressed by a score of "O" the inspector may make a deduction from the total score.

.........................................

Inspector.

*Adopted in part from the Dept. Agr., Bureau of Dairy Control, State of California.

**Factory Score Card.**—The foregoing discussion demonstrates the absolute necessity of good equipment and proper processing, if the bacterial content of ice cream is to be controlled. Unfortunately, all manufacturers are not scrupulous about these conditions, and it frequently becomes the function of the law to bring them into line. One of the best methods of control is the regular inspection of the factory with a score card.

The score-card method of inspection has two advantages. In the first place, it makes the work of the inspector thorough and systematic. Next, it tells the manufacturer plainly where and how much his factory is below par.

The score card itself is simple and easy to understand. The various factors have been weighed so as to give the proper importance to each condition.

## CHAPTER IX

# DEFECTS IN ICE CREAM

The manufacturer should have, above all things—an appreciation of the quality of his ice cream. Too often he labors under the delusion that his product is better than his competitors', and cannot understand why the consumer does not seek him out in order to purchase it. Such a condition may be termed sales egotism.

**Value of Scoring.**—If all ice cream were scored regularly by competent, disinterested judges, it would do a great deal to improve the quality. It is a well-known fact that the cities with the best milk supplies hold periodic scoring contests, in which all the scores are published. Naturally, under such conditions, all producers and dealers are constantly striving to be near the top of the list, inasmuch as this is a great factor in helping them retain old customers and secure new ones. Unfortunately, the ice cream manufacturer is given few opportunities to have his product judged in a competitive scoring contest. Under such circumstances, it is not a bad plan for the manufacturer to gather samples of his competitors' product and compare them with his own. Comparisons of this kind bring out defects more noticeably than an examination of one product only.

**Score Card.**—The quality of any dairy product may be determined systematically. The standards of quality for butter, milk, and cheese are well established. A universal score card has been worked out, and practically all of these products are judged on this basis. The ice cream industry, however, is newer and is going through so rapid a stage of development that no standards have been universally adopted.

Much discussion among various authorities on ice cream has resulted only in a great variety of score cards. The following table is indicative of the types suggested by some of the most prominent men in the industry.

It will be noticed that there are only slight variations in the numerical values assigned the several factors. It would be possible for competent judges to use any one of the given score cards in a comparative contest and give a relative position to the various entries. Giving proper

TABLE LXXV

VARIOUS ICE CREAM SCORE CARDS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Flavor | 35 | 35 | 45 | 50 | 40 | 35 | 35 | 40 | 50 |
| Texture and Body | 35 | 20 | 25 | 25 | 25 | 15 | 30 | 25 | 40 |
| Bacteria | 15 | 20 | 20 | 20 | 20 | 20 | 20 | 15 | |
| Fat and Solids | 10 | 15 | ..... | ..... | 10 | 20 | 10 | 10 | |
| Color | ..... | 5 | 5 | ..... | ..... | 5 | $2\frac{1}{2}$ | 5 | 5 |
| Package | ..... | 5 | ..... | ..... | 5 | 5 | $2\frac{1}{2}$ | 5 | 5 |
| Color and Package | 5 | ..... | 5 | 5 | | | | | |

emphasis to the various factors is a difficult task. The score card shown here, it is believed, will meet most conditions.

**Flavor.**—Flavor is given the highest value on the score card, because it is the most important factor in determining the quality of ice cream. In addition, it is the primary influence that motivates the consumer in buying ice cream. The ordinary individual, the man on the street, to whom the bulk of this product is sold, buys because he likes the taste of ice cream. The flavor appeals to him sufficiently to cause him to go into the nearest store and satisfy his desire. If the manufacturer, therefore, is to increase his volume of sales, he must turn out a product that, over a period of time, will have a flavor beyond reproach.

A desirable flavor in ice cream is the result of using only the best ingredients. Even when those of the proper quality are used, the resultant product often has an off-flavor because of improper blending or processing. A score of 30–38 on flavor indicates a noticeable defect, the cause of which usually can be identified. Ice cream with a highly excellent flavor may score above 38 and even as high as 41 or 42, but thus far none has been given a perfect flavor score. It is doubtful whether any judge will score a sample as perfect, because of the variation in personal opinion as to what really constitutes a perfect flavor.

**Texture.**—Ice cream sells more readily than sherbets or ices, largely because of its texture and body when frozen, and because of the fact that it is not as cold as sherbet or ice. Because of its smoothness and apparent creaminess, the consumer feels that he is getting more in a dish of ice cream than in a dish of sherbet or ice. The layman probably notices the texture more than any other factor, no doubt because it requires less observation or keenness to note body defects. Only a discerning individual may decide when an ice cream is off-flavor, but anyone can tell when it is rough or sandy. Manufacturers state that texture, more often than any other factor listed on the score card, is a source of complaint.

ICE CREAM SCORE CARD

Exhibitor. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Address. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Class. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Exhibit No. . . . . . .

| Item | Perfect Score | Score Allowed | Remarks |
|---|---|---|---|
| Flavor. . . . . . | 45 | | |
| Texture. . . . . | 25 | | |
| Bacteria. . . . . | 20 | | Bacteria per Gram . . . . . . |
| Color. . . . . . . | 5 | | |
| Package. . . . . | 5 | | |
| Total. . . | 100 | | Per Cent Fat . . . . . . . . . .* |
| | | | Per Cent T.S. . . . . . . . . . . |

Signed . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
Judges

Date. . . . . . . . . . . . . . . . . . . . . . .

*In contests, ice cream not conforming to state legal butterfat standards, or that containing less than 34 per cent solids, shall be disqualified.

BACTERIA PER GRAM—PERFECT SCORE 20

| | Points |
|---|---|
| 50,000 and under. . | 20 |
| 50,001– 75,000. . . . | 19 |
| 75,001–100,000. . . . | 18 |
| 100,001–125,000. . . . | 17 |
| 125,001–150,000. . . . | 16 |
| 150,001–175,000. . . . | 15 |
| 175,001–200,000. . . . | 14 |
| 200,001–225,000. . . . | 13 |
| 225,001–250,000. . . . | 12 |
| 250,001–275,000. . . . | 11 |
| 275,001–300,000. . . . | 10 |
| 300,001–325,000. . . . | 9 |
| 325,001–350,000. . . . | 8 |
| 350,001–375,000. . . . | 7 |
| 375,001–400,000. . . . | 6 |
| 400,001–425,000. . . . | 5 |
| 425,001–450,000. . . . | 4 |
| 450,001–475,000. . . . | 3 |
| 475,001–500,000. . . . | 2 |
| 500,001–525,000. . . . | 1 |
| 525,001 and over. . . | 0 |

(Usually printed on back of score card.)

Texture and body are included under one head. It is doubtful whether an accurate, clear-cut differentiation can be made between the two. Many criticisms that really relate to texture defects are reflected in the flavor score by both the judge and the consumer. The flavor score is invariably lowered if the texture is markedly defective. As soon as the factors affecting it are remedied, however, the flavor score increases accordingly. Too much care and attention cannot be given to the inspection and study of texture. Since judges know quite definitely, and agree upon, what constitutes a perfect texture, it is not uncommon for them to score it the full 25 points. The judge should not be reluctant to cut and criticize texture. Often as many as 5 or 6 points are deducted.

**Bacteria.**—Bacteria are noted on the score card solely in order that a criterion may be set for the quality of the products used and the cleanliness with which they have been handled. It is realized that types of bacteria are more important than the total number present, but in work of this kind discrimination is hardly possible. The standard selected works out very satisfactorily under the condition that pasteurization of the entire mix be required.

Practically all authorities agree that the consideration of bacteria on the score card leads to a more wholesome product. The score allowed for the number present operates on a sliding scale, 50,000 or fewer being allowed the full 20 points. It is not difficult for a manufacturer using the required amount of skilled help and the proper kind of ingredients to manufacture uniform ice cream containing on the average 25,000 or fewer bacteria to the gram.

**Color.**—Any food product is relished more when it is pleasing to the eye. As a matter of fact, there is more or less correlation between the appearance and the taste. Unfortunately, American cookery has devoted too little attention to the appearance of food. The American people seem to want their food served to them quickly, and sacrifice appearances as a result. This is no doubt the reason for the astonishing number of various types of quick-service restaurants in America, and for their popularity, for nowhere else in the world is it possible to find a lunch counter or cafeteria, or be served food, as quickly as in America.

It is a simple matter, however, for the manufacturer to color his product properly. A poorly colored product in a row of ice cream samples is very noticeable, even to a casual observer. True, color is given a low numerical value, but the score card is believed to be properly balanced, considering the importance of the previous factors.

**Package.**—Though the ice cream container does not come to the consumer's notice as does the butter package or the milk container, it

has just as direct an influence upon the quality of the product it contains. Rusty cans may be wholly responsible for off and metallic flavors. Since the container may even be a source of bacteria, it quite properly finds a place in the score card, and the weight assigned it seems quite justifiable.

**Fat and Solids.**—Fats and solids are not given a numerical rating on the score card, although they may play an important part in competitive judging. State standards take ample care of the butterfat standard, while competition forces the manufacturer to maintain a fairly uniform fat, in many cases as close to the minimum standard as the law allows. No premium is allowed on the score card for high fat, because an increase in butterfat beyond commercial limits is naturally reflected in the flavor score. It is difficult to determine by taste alone a difference of 1 or 2 per cent in the butterfat content of ice cream, except perhaps by the slightly increased palatability. Solids are placed on the score card at a minimum of 34 per cent of the total, since it is believed that an amount less than this does not give sufficient palatability or food value to the ice cream to enable it to receive continued favor with the public and health authorities. Sooner or later all the states will follow California's lead and require a certain percentage of food solids (food solids being defined as butterfat, milk solids-not-fat, and sugar) per volume of frozen product. When that time arrives, the total solids in ice cream will be taken care of in the same manner as butter fat is at present.

**Method of Scoring.**—The scoring of ice cream is done most conveniently by comparing samples under conditions similar to those under which they are consumed. It is quite difficult to place a correct score on an individual sample of ice cream, although certain flavors and certain defects may manifest themselves in it. The ice creams to be scored should be dipped at a uniform temperature into convenient containers, such as paper plates. These should be placed in a room where they may be observed during melting.

Before the sample is taken, at least one-half inch should be removed from the top of the can, note being made of whether it was capped with parchment and of the condition of the can. A uniform amount should be dipped into the plate. Care should be taken not to mash the cream against the side of the can or to exert excessive pressure on the dipper when scooping. The grain, stickiness, and color should be observed during the dipping. Some creams have a tendency to roll under the dipper; others are decidedly sticky and soggy, and even though a uniform temperature be maintained, some are much harder than others. This indicates to some extent the amount of overrun and the amount of

solids, mostly sugars, in solution. The dipper should be washed in clean water after each sample is taken, in order not to mix the flavors. This is particularly necessary in a scoring contest where a large number of samples are to be dipped. A metal spoon, rather than a wooden one, should be used when examining the sample. Flavors are likely to be transmitted with the wooden spoon, and the texture is difficult to ascertain. If the metal spoon is held loosely in the hand and inserted into the cream in the dish, the iciness or crystal formation can be easily detected. All samples should be treated in the same manner. If some are torn apart more than others, they have more area exposed to melting and may thus invite a criticism that is not really justifiable. The color of the ice cream should be examined soon after the samples have been lined up for judging. In contest work, all samples should be identified by number, rather than by the manufacturers' names, so that the scoring may be absolutely unbiased. A judge may be unconsciously influenced if he knows the name of the manufacturer.

Ice cream should have a texture that is smooth, firm, close, and free of crystals of all kinds. When placed in the mouth, it should contain enough solids to indicate substance and at the same time not be soggy or too heavy. A lack of solids, which is usually accompanied by the formation of larger ice crystals, may be due to the incorporation of too much air. To be most palatable, ice cream should not be served in its hard, frozen condition, but should be soft enough to be smooth and creamy. Melting should take just a little longer time than that required, under ordinary conditions, to consume a generous serving of ice cream. The melted ice cream should have sufficient viscosity to be palatable to taste and pleasing to sight. The casein, therefore, should be left in as nearly normal a condition as possible, and enough solids should be incorporated into the mix to prevent the watery, low-solids appearance that is so common in melted ice cream.

The flavors of ice cream in the frozen condition are not readily detected. The cream has to be melted in the mouth in order that odor and flavor may be detected. A poor grade of vanilla is evidenced by the coarse, bitter flavor so characteristic of the materials used in making extract of a low grade.

A good judge never swallows the ice cream, or he would soon lose his keen sense of taste. Needless to say, he must be able to identify flavors. Rinsing out the mouth with water after the scoring of each sample is conducive to greater accuracy in this respect. Cleanliness, of course, should be strictly observed.

**Accuracy of Scoring.**—It is said that expert judges are born and not made. This is not altogether true. A good judge must be a careful

workman with a keen sense of taste and smell, and must be very familiar with the products that are used in the manufacture of ice cream in order that he may know the causes of certain flavors. Most people possess sufficiently keen senses of taste and smell to enable them, with practice and a thorough knowledge of the industry, to become quite expert in judging quality. When more than one judge scores, as should be the case in educational contests of State and National Shows, each should work independently. Consultations should not be held. The scores should be turned in to the secretary, and should agree quite closely. When this is not the case, the sample should be re-scored without the former scores being made known. It is true that slight differences of opinion and slight differences in evaluation of certain defects may exist between judges, but in practice among good judges these differences do not affect the score to any great extent. On the score card suggested, a good ice cream should rate not lower than 93. It is not uncommon for a sample to be scored several points higher when exceptional quality is encountered.

The ice cream should be scored as found. Certain defects, however, such as rancidity, should be cut quite severely, even though they be slight at the time, since they indicate that the product will be unmarketable in a short length of time. The treatment ice cream receives in the cabinets at the dealers' fountains may bring out its defects and cause it to deteriorate quite rapidly.

Some of the Common Ice Cream Defects

Flavor:
- Bitter
- Cooked
- Egg powder
- Flat
- Foreign
- High
- Lacking sweetness
- Metallic
- Neutralizer
- Old butter
- Old cream
- Salty
- Rancid
- Sour
- Stale
- Too sweet
- Unnatural
- Unclean

Texture and Body:
- Soggy
- Coarse
- Weak
- Sticky
- Watery
- Sandy
- Gelatin lumps
- Fluffy
- Buttery
- Icy
- Crumbly

Color:
- Too light
- Too high
- Unnatural
- Uneven

Package:
- Rusty
- Dented
- Not full
- No parchment

If the scoring can be done by ice cream makers, it has an additional educational value, in the establishment of ideals for producing more uniform ice cream. The entries in the contests held in California for the last six years, the last five being held in connection with the Pacific Slope Dairy Show, clearly indicate the value of commercial ice cream scoring. At first, practically every imaginable color of ice cream was shown; while in 1926, with one exception, all samples were almost identical in this respect. Uniform quality over a large area is bound to react in increased consumption.

## FLAVORS

**Bitter.**—This flavor is quite uncommon in ice cream. It is easily distinguished by its peculiar astringent effect on the tongue. A bitter flavor in ice cream may or may not be intensified upon holding, depending upon the source of the bitterness.

Bitterness usually results from the use of a poor grade of vanilla. It may be caused, however, by a poor quality of milk and cream. Weigmann[1] states that bitterness in dairy products may be caused by pasteurizing the milk proteins, which yield bitter-tasting albumoses and peptones. Certain types of bacteria, such as *Streptococcus casei amari*, have been reported by Jensen[2] as a source of bitter flavor in milk. In some ice cream plants, standardization of the acid is a common practice. Where lime is used as the agent to standardize the acid and where an unusual amount of acid has been reduced, bitter flavors may be produced, not so much by the amount of lime used as by the method of adding it. If lime is to be used, it should be added slowly at the time of pasteurization when the mix is approximately 90° F. and while the mix is being agitated. (See Chapter X.)

Obviously, the remedy for bitter flavor is better ingredients.

**Cooked.**—A cooked flavor, which is quite common, has nothing to do with the keeping quality of ice cream. It is usually derived from improperly pasteurized mix and from the use of poor condensed or poor skim-milk powder. It should not be confused with an oil flavor, for the two have nothing in common.

Often the heating medium is too hot or the agitation is too slight to remove the mix from the heating element fast enough to prevent a part from being scorched during pasteurization. Too high a temperature at this time invariably imparts a cooked flavor. The condensed product, too, whether plain or sweetened, often imparts a cooked flavor to the

[1] Weigmann, Otto, Mykologie der Milch, 1911, p. 132.

[2] Orla-Jensen, P., Die Bakteriologie der Milchwirtschaft, p. 82.

cream. This may be due to the superheating of the condensed product, to pasteurization temperatures that are too high, or to the improper operation of the condensing unit. Improperly manufactured powder or a poor type of drying unit may also be contributing causes. Then, too, certain types of powder invariably impart to the ice cream a pronounced cooked flavor, while others give only a very slight one.

The remedy is to be found in improved methods of pasteurization or in the use of better products.

**Egg Powder.**—In mild cases, egg-powder flavor is hard to distinguish from cooked flavor. With a poor grade of egg-powder, however, the flavor is easily detected. An off-flavor derived from this source is very objectionable, as it indicates an insanitary method of manufacturing the powder. The flavor is disagreeable and highly objectionable.

The remedy is to use a better grade of egg-powder, or to omit egg-powder altogether.

**Flat.**—Ice cream is said to possess a flat flavor when it lacks the delicate aroma and flavor found in that of the best quality. This defect is not so objectionable in itself. If insufficient flavor is used, the flavor of the dairy products is allowed to show through. If all of these are of the best quality, the cut on flavor should be very slight.

The remedy is the use of an additional amount of good flavor.

**Foreign.**—Often the judge will encounter peculiar off-flavors, the source of which may be unknown. They are chiefly due to certain types of bacteria. In the manufacture of ice cream, the sources of materials used are so varied that when the products are blended together a new or peculiar flavor at times may result. The score on such a criticism depends entirely upon the intensity of the defect. The sample is not usually cut severely. When the flavor is very pronounced, its source can often be identified.

**High Flavor.**—High flavor, as may be inferred, is the result of using too much flavor. The quality may have been excellent, but too much has been used, making the product objectionable. The remedy is self-evident.

**Too Much Sweetness.**—The sweetness in ice cream comes largely from the sucrose, either beet or cane, although in some states corn sugar (dextrose) is used to some extent to replace a portion of the sucrose. The ice cream manufacturer has learned that an increased solids content smooths up the finished product. After the maximum amount of sucrose has been used, corn sugar is often added in an effort to produce a smooth cream without obtaining too much sweetness. Sugar is one of the cheapest sources of solids in ice cream and is used to a considerable extent. Ice cream that is too sweet is sickening to the taste

and is not conducive to the proper consumption. When used excessively, sugar lowers the freezing point to such an extent that the ice cream becomes soft when it is held under ordinary cabinet conditions.

The remedy is to reduce the sugar content of the mix.

**Lacking Sweetness.**—Ice cream with low sweetness is seldom encountered, for, as was pointed out above, sugar plays such an important part in the mix that the tendency is to use too much rather than not enough. Ice cream lacking in sweetness is generally open, coarse, often icy and excessively hard when held in a cabinet at the usual storage temperature. If insufficient sugar is added, the product generally lacks smoothness and richness of flavor as well as food value. The correct amount of sugar is very desirable.

The remedy is an increased amount of sugar.

**Metallic.**—Metallic flavor is very objectionable and is quite often found in ice cream. A poor grade of vanilla will often give a suggestion of metallic flavor. This flavor is generally understood to give the semblance of an astringent or puckery condition characteristic of such salts as those of copper and iron. The defect is usually quite evident and is generally accompanied by other off-flavors. When found in a fresh cream, even in a very mild form, it should be criticized quite severely, for it will become more pronounced as the cream ages. In fact, within a short time an ice cream having a metallic flavor becomes unsalable, for cold storage temperatures do not check the development of this flavor.

The causes of metallic flavor are somewhat varied. The use of old rusty milk cans or of copper vats whose tin lining has been worn away, thus exposing the copper, is undoubtedly responsible in many cases. The increasing popularity of glass-lined equipment in the last few years may be partly accounted for by the desire to avoid this flavor. Sweet butter, which is often used as a source of fat in ice cream, sometimes imparts a metallic flavor, particularly when it is made from sour or neutralized cream in a factory with poor equipment. Some manufacturers make their mix in copper condensing pans. As a usual thing, mix made by this method should have no more metallic or off-flavors than one made by the usual method. If the pan is not thoroughly cleaned, however, metallic flavors will result. A very small quantity of copper salts added to a quantity of mix also produces the characteristic metallic flavor. While from two to three days are required after the addition of the salt for the flavor to become noticeable, it continues to develop and in five or six days sometimes renders the product unmarketable. The same thing applies to condensed skim, either plain or sweetened. Copper pans are used in the manufacture of practically all

of the condensed solids. The condensed product, therefore, even in the form of powder, is a potential source of metallic flavor. Guthrie[3] states that it may be developed from a certain type of bacteria which is a member or a strain of the *S. lactis* group, or from certain enzymes. Hunziker[4] makes the following statement:

> Attempts to attribute the metallic flavor to the presence in the cream of specific bacteria or groups of microörganisms experimentally, have proved abortive. While bacteria, through their power to decompose portions of the ingredients of cream and butter, forming acid and other cleavage products, may assist to a limited extent in the production of metallic flavor, they cannot be considered as the specific cause of this defect.

The prevention of this flavor depends upon the use of well-tinned equipment or of glass-lined containers, if practical, and upon the enforcement of sanitary measures.

**Neutralizer.**—This flavor is quite uncommon in ice cream, though the standardization of acid in mix is not unusual. It is true that if a neutralizer is used, it remains in the ice cream, though this is not the case with butter. The neutralizer used on cream before the butter is manufactured is drawn off with the buttermilk; in ice cream it remains in the finished product. While none of the approved neutralizers are detrimental to health, particularly in the quantities that are used in an ice cream mix, the possibility of their abuse is evident. They should never be used in an ice cream mix that has developed a sour flavor. There are many neutralizers which could be used in standardizing the acid. The effect upon the mix differ, depending upon the neutralizer used. Cream that has been neutralized to any marked degree is often subject to oxidation.

A neutralizer flavor is detected by a slight burning and contraction in the back of the mouth. An ice cream mix probably need not have the acid reduced more than 0.05 of 1 per cent at the most and, if the neutralizer is properly prepared and added, no off-flavor directly due to neutralizer need occur.

The remedy for this flavor is the use of good quality material with as nearly uniform acid as possible.

**Old Butter.**—It is difficult to identify an old-butter flavor in ice cream, even though the off-flavor be detected. When stale butter is used, it will cause a stale flavor in the ice cream. If too old, it may be slightly rancid. In such case the ice cream is termed rancid.

There is a certain relationship between old cream, old ingredients,

[3] Guthrie, Bul. 373, Cornell, 1916.

[4] Hunziker, O. F., The Butter Industry, 1920, p. 485.

and old-butter flavor, but it is difficult to segregate them when they are found in ice cream.

Since an old-butter flavor in ice cream is due to the quality of the butter used, the remedy is apparent.

**Old Cream.**—All that was said concerning the old-butter flavor applies to that arising from the use of old cream. These two products are used largely as a source of fat. It is evident that improper handling of them will appear as an off-flavor in the ice cream. A better grade of product will eliminate this defect.

**Salty.**—Salty flavor is usually due to the presence of too much sodium chloride. In the past, some manufacturers have added a small quantity of sodium chloride to the mix. This idea undoubtedly was taken from the butter industry. It is a well-known fact that salt brings out the flavor of butter. Ice cream of a few years ago contained slightly more fat than the present-day product, although the latter has more food value and a better nutritive ratio, and is far more palatable than its predecessor. Modern practices do not call for the use of salt. The most common cause of this flavor to-day, therefore, is leaky cans or brine contamination during the handling and storing previous to the time the ice cream reaches the consumer.

The remedy for this flavor is to eliminate the use of salt in the mix and to use sound containers. In case the brine gets into the ice cream after it is well hardened, the cream can be saved without any material damage by simply taking off the outer layer. Saltiness is a defect quite often met with in small brick deliveries. In such a case, rinsing the brick under the faucet easily removes the salt water without any particular injury to the quality of the cream.

**Rancid.**—Rancidity is a very objectionable flavor, indicating poor quality of ingredients and insanitary conditions. It is usually due to a decomposition of the butterfat in a poor grade of cream or butter. In some instances, the equipment is not properly cleaned, considerable fat being left on the walls or coils. This becomes rancid and contaminates the mix. The cause of this flavor is the same in any case, though the source of contamination may be varied. The splitting of the fat, causing this highly undesirable flavor, is probably due to bacterial and mould action. There is usually enough protein and lactose present to provide the proper food elements for the growth of this type of bacteria. Recently, considerable thought has been given to enzymes, and it is very possible that part of the rancid flavors are due to enzymatic action. Ice cream mix itself very seldom becomes rancid. There seems to be an association between the amount of acid present and rancidity. An ice cream mix usually is fairly low in acidity, and, since it is handled rapidly,

there is very little chance for rancidity to develop if the equipment is in good condition and the ingredients are of the right quality.

The use of rancid nuts may be an unlooked-for source of rancidity in ice cream.

The amount of air in ice cream has a bearing upon the amount of hydrolysis that takes place, just as air affects the hydrolysis of butter. This hydrolized flavor is criticized as rancid. It is easy to see that this is a very serious defect, as the flavor is easily detected by the consumer. Any ice cream held in storage long enough, regardless of the quality of the products from which it was manufactured, may develop a slight rancid flavor. In its early stages, this flavor is more often referred to as stale—not that there is a particular relationship between these two criticisms—but as the cream becomes older, this flavor becomes more pronounced and is more easily identified.

To remedy this condition, dairy products of better origin should be used and the length of time the ice cream is kept in storage should be limited. Any milk, cream, or butter that has a slight rancid flavor should be discarded. Its use may escape unnoticed for a short while, but a sound business cannot be developed with this class of product. Unfortunately, the manufacturer who uses products of this kind not only injures his own sales but casts a smirch upon the whole industry.

**Sour.**—Sourness is probably discriminated against more than any other flavor that ice cream could contain. While rancidity is highly objectionable, the customer does not seem to retain the memory of this particular flavor as long as that of sourness. Ice cream that is sour is unmarketable. Manufacturers know that it is a waste of time and money to attempt to deliver such ice cream. The cause of this defect lies in the improper handling of one or more of the dairy products. Sour ice cream has not been produced under sanitary conditions or has not been held at low enough temperatures to prevent the development of acid-producing bacteria. There are almost always other flavors accompanying this one. In addition to the types of organisms which produce the sour flavor, many other organisms are growing also. A sour ice cream very often has an unclean flavor as well. The texture and body are always defective, since the acid tends to make the protein brittle.

**Stale or Old.**—The stale flavor is generally caused by holding ice cream too long in the cold storage box. It usually will become rancid if held long enough.

The remedy for stale-flavored ice cream is to stock less heavily and to work for a more rapid turnover. Staleness is usually encountered during the winter season.

**Unnatural.**—Unnatural flavor refers more specifically to artificial flavors. With artificial flavoring it is almost impossible to obtain a true strawberry flavor. Some manufacturers are using certain artificial vanillas that are harsh and unnatural. Some of these contain no vanilla and are crudely put together. Ice cream with a desirable flavor and aroma cannot be obtained with the use of cheap grades of flavoring. There is entirely too much low-grade vanilla extract used at the present time. The cost per gallon is not excessive, even if the best grade of vanilla is used. Anything that tends to increase the palatability of ice cream and thereby to increase its consumption, even though the increase be slight, readily pays for the small additional cost of a high-grade extract. These same remarks apply to other flavors.

**Unclean.**—The word unclean suggests improper handling of the mix. An unclean, dirty flavor is highly objectionable. It is usually associated with high bacterial counts and a product of low grade. Pipe lines or small, inaccessible places in the equipment are often accountable for this flavor, which exists entirely too often in ice cream. Some pieces of equipment which the manufacturer is compelled to use are not so constructed as to be cleaned and sterilized easily. Since some states are putting into their statutes a bacterial standard, changes will no doubt be made in the construction of some pieces of equipment so as to allow easy cleaning and sterilizing.

Improper methods of production used by the dairyman constitute another important source of unclean flavor.

The remedy for this flavor is cleanliness. Cleanliness, as a matter of fact, is paramount in the production of a high-grade ice cream.

## TEXTURE AND BODY

**Soggy.**—Sogginess is not a very common defect in commercial ice cream, but is nevertheless objectionable. It is due usually to the incorporation of an insufficient amount of air. Bread would be very unpalatable if the loaf were not allowed to rise before being baked. This increase in volume in bread and decrease in weight in order to obtain the desirable characteristics is comparable to the freezing of ice cream, in which air is incorporated to a certain percentage, thereby effecting a more palatable product. If insufficient air is incorporated, a soggy, heavy, doughy body results, which is unpalatable and objectionable to the trade. Certain small manufacturers who have not the facilities properly to manufacture their product often have a soggy ice cream. The selling price of the product has been set with this knowledge, and ice cream not containing the desired amount of air may be unprofitable to the manufacturer.

**Coarse.**—Coarseness is a defect found in most ice cream. The process of manufacture has not been improved to such an extent as to eliminate this criticism completely. Occasionally, an ice cream may be found that has the desired smoothness and that is close in texture. Just what factors must be controlled in order to obtain a product of sufficient and uniform smoothness is not definitely known. The higher the percentage of solids in the mix, the smoother the product, all other factors being equal. A low-solids ice cream is prone to be coarse and grainy, although it may be heavy in weight per volume and still may not be soggy, since the percentage of total solids may be low while the food solids per volume are normal because of the percentage of yield obtained. Therefore, the control of the weight of a definite volume of ice cream does not necessarily mean that a desirable product will be manufactured unless some provision is made for the total solids per volume.

**Weak.**—The use of insufficient stabilizer results in a weak ice cream. Certain edible stabilizers, one of which is gelatin, enable the manufacturer to assemble, process, harden, deliver, and dispense his product to the consumer in its most desirable form. If a low-grade stabilizer is used, the ice cream melts too rapidly; it lacks body, even though it may have other solids present, and it has a tendency to appear watery and lacking in substance.

**Sticky.**—Sticky ice cream is usually the result of using too much stabilizer or one of the wrong kind. It is a doughy condition somewhat similar to sogginess and just as objectionable. If the trouble can be attributed to the stabilizer, the ice cream will be resistant to melting. An ice cream that will not melt is immediately branded by the consumer as undesirable and probably adulterated. He is not familiar with all the ingredients used and cannot understand why the ice cream does not melt as rapidly as that made at home where a stabilizer has probably not been used.

**Watery.**—A watery condition is a defect in ice cream usually caused by the improper use of enzymes or improvers or by an insufficient amount of solids. Melted ice cream should be somewhat viscous, having the appearance of a 38 or 40 per cent whipping cream. One that is low in solids tends to separate and whey off on the outer edges, giving the appearance of milky water. When enzymes have been used improperly, the casein is coagulated and the water is allowed to separate and melt down, showing a curded condition. Even though only a slight amount of enzyme has been used, close examination will show the curdy condition. An enzyme used in a normal mix, fresh from the cooler and frozen immediately, produces a smoother-textured cream which requires less time to freeze.

**Sandy.**—Sandiness is the result of the crystallization of milk sugar. The milk solids-not-fat contain slightly more than 50 per cent of milk sugar (lactose). If an excess of milk solids-not-fat is put into the mix and pasteurized, a supersaturation of lactose will exist. Since lactose is the most insoluble sugar in ice cream, it is the first one to crystallize, forming hard, quite insoluble crystals. These naturally make the texture of the ice cream rough. The method of correcting this condition is to use a smaller amount of milk solids or a process whereby the milk-sugar content of the milk solids-not-fat is decreased or is put into such a state that the crystals do not form in the finished product.

Nut ice cream seems prone to become sandy. This may be attributed to the fact that the nuts act as nuclei for crystallization. This theory seems to be well founded, since ice cream with a high percentage of nuts becomes sandy more quickly than one with a low percentage.

**Gelatin Lumps.**—This defect is very uncommon in commercial ice cream. The average manufacturer either prepares his gelatin in water before adding it to the mix or else sprinkles it over the mix during the pasteurization process. This allows the gelatin to go completely into colloidal solution and makes it impossible for gelatin lumps to appear in the finished product. Some manufacturers, however, stir the hot gelatin solution into the cold mix. This method often does not allow the gelatin to be dispersed through the mix rapidly enough to prevent the formation of small strings or lumps. It is not unusual to find on the strainer, which is on top of the freezer, a quantity of gelatin shreds or lumps, the result of the gelatin being added improperly. Since it is impossible to strain out all of these, they appear as gelatin lumps in the finished product. In case the mix is not strained and is used in a tub freezer, the criticism may be quite severe.

**Fluffy.**—A fluffy ice cream is one that has incorporated too great a percentage of air or gas in relation to the percentage of total solids in the mix. Such an ice cream, when taken into the mouth, disappears or melts rapidly. The layman is quick to criticize this defect of texture and body. Health officials and ice cream retailers have striven for the past few years to have ice cream sold by weight, hoping thus to eliminate ice cream with an excessive yield. (See Control of Yield, page 197.)

The loading of ice cream with air is highly objectionable and is practiced by only a few manufacturers. Producing fluffy ice cream injures the confidence of the public in the industry.

**Buttery.**—Small butter granules may appear in the finished product. The last can drawn from the freezer is usually the most defective in this respect, for the granules collect on the dasher blades and are generally discharged toward the end of the run. These granules are due either

to the lack of homogenization or to improper homogenization. It is almost impossible for a commercial manufacturer to produce an ice cream free from butteriness if he fails to homogenize the mix. Some homogenizers are really only pumps, and actually afford very little homogenization. A buttery condition is the result. This can be avoided either by servicing the homogenizer, or, in the case of unhomogenized mix, by putting the mix into the freezer as near the freezing point as possible. Such a practice allows solidification of the fat in its natural form before it has time to coalesce and form butter granules.

**Icy.**—Iciness is differentiated from sandiness by the fact that the ice crystals are very soluble, being nothing but frozen water, while the sand crystals are insoluble. Low-solids ice cream mix is quite prone to form ice crystals. When drawn from the freezer in a soft condition, ice cream is subject to the formation of ice crystals. Even though it be frozen properly, drawing it into warm cans tends to cause the melting of a layer around the outside of the can, and during the hardening process this layer becomes icy. Most manufacturers know how to avoid iciness in the latter case. However, where an ice-and-salt cabinet is used, the alternate hardening and softening of the cream results in a gradual separation of the water from the solids, to such an extent that the formation of ice crystals may occur. This is especially true during the winter season when there are successive days of hardening and softening before the ice cream is sold. The use of iceless cabinets by the retailer has helped to eliminate this condition.

**Crumbly.**—Crumbliness in ice cream, unless quite pronounced, is not a very serious defect. It simply means that the ice cream fails to stick together. It may be smooth to the taste, fairly close in texture, and free from ice crystals. To eliminate crumbliness requires an adjustment in the relationship between the different solids. Increasing the sugar tends to produce an ice cream free from crumbliness. An increased amount of gelatin may also help in eliminating it.

## COLOR

**Too Light.**—An ice cream that is chalky in appearance is not nearly so pleasing to the eye as one with a light creamy color. The public has long associated a certain color in vanilla ice cream with "richness." In strawberry ice cream, too light a strawberry color gives the impression that only a small amount of fruit has been used.

Ice cream containing too much color is even less desirable than that containing too little. Over-coloring regardless of the flavor produces an artificial appearance. The public, while it may not ask, naturally con-

cludes that the high color is artificial and then almost invariably finds many other defects in the cream which may or may not exist.

**Unnatural.**—A few years ago, almost any shade could be found in vanilla ice cream, from no color at all to yellow (all shades), lemon, orange, etc. These off-color creams are gradually disappearing, and the manufacturer is learning the consumers' preferences. A color that gives to an ice cream the true shade of butterfat is far more desirable. Some certified colors blended together may be used quite satisfactorily. Often, however, a tinge of green accompanies a yellow, and yet again orange or lemon. All of these are recognized by the consumer as artificial. Cheese color makes a highly desirable color for vanilla ice cream. Butter has been colored for years, with the idea of producing a uniform shade throughout the seasons. It has also been customary, for a long time, to add color to cheese. There can be no other reason for using cheese color except to make the product more attractive. Anything that tends to make a product more attractive to the eye tends to make it more palatable.

**Uneven.**—Uneven color is an unusual defect and is not very serious. It is usually found where color has been added to the freezer after the cream was practically frozen. In such a case sufficient time is not allowed for the color to be distributed through the mix. This can be easily remedied by adding the color at the proper time. If a uniform amount is not added, a can filled from two different runs is apt to have a break in color.

## PACKAGE

**Rusty.**—Rusty cans are subject to criticism by health departments, and sometimes by dealers. The consumer sees but little of the can in which the cream is delivered. The use of a can or package that has the appearance of cleanliness and of being well kept tends to impress upon the purchaser that the product inside the container is of equal quality.

**Dented.**—Dealers often object to dented cans, feeling that they are receiving less volume than they are paying for. In reality, however, very few dented cans affect the volume to any extent. Nevertheless, the impression left with the dealer that the manufacturer's equipment is not correct may lead to dissatisfaction and may even be the means of losing his account.

**Not Full.**—It is highly desirable that a can be filled. All cans on the market to-day hold practically the amount for which they are intended. A can that lacks one-half or one-quarter inch of being full is objectionable, and dealers will complain if such cans are delivered to them. They

are paying for a full container and are entitled to it. The practice of some manufacturers of over-filling cans is just as undesirable, for the dealer soon comes to expect all cans to be over-filled. Striking the cans level with the top is a practice to be recommended. The ordinary increase in volume during the hardening process is sufficient to fill a can neatly and completely. The value of uniformity of cans to the dealer is worth the cost of the extra labor.

**No Parchment.**—All cans should be capped with parchment paper before being lidded. This serves as a protection from salt and brine leaks around the lid, and prevents contamination from the lid, which is not often given the same sanitary attention as the can, although it should receive just the same care.

## CHAPTER X

## METHODS OF ANALYZING DAIRY PRODUCTS USED IN ICE CREAM MAKING

In order to manufacture and control economically the quality of ice cream, it is necessary to make frequent tests of the raw materials used as well as of the finished product.

Though in many cases there are several methods of making the same test, detailed instructions are given here only for those methods which are most commonly used or are most accurate when speed, simplicity, and economy are important factors. Other methods, which may be found preferable under certain specialized conditions, will be mentioned.

In testing, it should always be remembered that the sample must exactly represent, in composition, the can of milk, tub of butter, or other product from which it is taken. This is true when the sample is taken for the laboratory or when it is measured into the test bottle. Every precaution should be observed in obtaining and caring for the samples.


*Courtesy Creamery Package Mfg. Co.*
Fig. 68. Fig. 69.
Recommended Types of Sample Bottles.

Sample bottles should be large enough to accommodate the sample and should have a convenient method of identification, preferably an etched surface on which one can write in pencil. They should also be easy to clean and should be fitted with a stopper to prevent leaking and spilling. A screw cap with tight rubber gasket is best, though paraffin paper caps can be used if samples are to be tested within forty-eight hours.

### METHODS OF ANALYSIS FOR BUTTERFAT

**The Mojonnier Method.**—This method may be used to determine the fat content of all dairy products with a greater degree of accuracy than any other method adapted to commercial conditions. It requires the

use of the specially constructed Mojonnier Tester, with which is furnished complete instructions[1] for analyzing all dairy products. Those details, therefore, are not repeated here. The main disadvantages of this method are that it is expensive to install and requires a highly trained and careful operator.

The principle of the Mojonnier Method is similar to that of the Rose-Gottlieb, where the solids-not-fat in a weighed sample are dissolved by ammonia and the fat extracted with ether. The ether-fat solution is then decanted, the ether evaporated, and the fat weighed directly. The percentage of fat is calculated from the weights of the sample and the fat.

**The Babcock Method.**—This method was invented by Dr. Babcock and given to the world in 1890. It is based on the principle of dissolving the solids-not-fat with sulphuric acid, bringing the fat to the surface by centrifugal force and collecting it in a tube calibrated to read directly in per cent. Because of its wide adaptability, low cost of installation, and simplicity of operation, it has been almost universally adopted in this country for determining the fat content of dairy products.

*Milk*

The bottle for sampling milk should be clean and dry, to prevent any dilution or adulteration. The milk must be thoroughly mixed, preferably by pouring from one container to another four or five times. If any other method of mixing is used, great care must be exercised to get a homogeneous emulsion of the fat. At least 1 oz. of milk should be taken, to insure a sufficient sample for three or four determinations, if necessary. It should be carefully labeled and kept in a cool place until tested. If samples are to be transported long distances, the bottles should be filled to capacity, to prevent agitation and churning. A preservative is usually added.

A composite sample is made up of simple samples of two or more lots of milk and is used to save time, labor, and material. When properly taken and cared for, it gives results which are practically as accurate as daily samples. Care must be taken to have the amount of milk in each simple sample proportional to the quantity from which it is taken. This is especially important when two lots of milk vary widely in either amount or fat content. Composite samples should contain at least 75 c.c. of milk. A preservative should be added because they are usually kept from ten to fifteen days before being tested. The bottles should be full if they are to be transported long distances.

[1] Complete instructions are given in "The Technical Control of Dairy Products," by Mojonnier and Troy, published by Mojonnier Brothers.

Corrosive sublimate is the most satisfactory preservative. It is obtained in the form of colored tablets, which are readily soluble in milk. Those prepared by the citric method should not be used, as they will cause lumps of curd, making impossible a smooth mixture for pipetting. Dairy supply houses may usually be depended upon as a satisfactory source from which to purchase, since they are familiar with trade demands. One tablet should preserve a half-pint sample for a period of two weeks. Not more than 1 per cent of the total weight of the sample should be added, however. Corrosive sublimate has the disadvantage of being a violent poison.

Formalin, or formaldehyde as it is commonly called, makes a satisfactory preservative. Usually two drops per ounce of sample is sufficient. It has the following disadvantages.

1. It occurs as a liquid and is troublesome to use.
2. It hardens casein, making it difficult to dissolve.
3. It is colorless and, therefore, its presence in milk is not visible.

Potassium bichromate is the least satisfactory preservative. About 1 gram is necessary for the preservation of 1 pt. of milk. As with corrosive sublimate, not more than 1 per cent of the total weight of the sample should ever be added. It has the following disadvantages:

1. It dissolves with difficulty in milk.
2. It hardens casein, like formalin.
3. It gives the milk a rich yellow color and its presence may, therefore, be unobserved.

When any of these preservatives are added to milk, they should be thoroughly mixed with the sample each day. This helps to prevent fermentation, checks the growth of mold, and keeps the fat from forming a tough, hard layer on the top of the milk.

**Preparation of Sample.**—The sample should be warmed to a temperature of 60° F. and thoroughly mixed by pouring three or four times from one bottle to another. Pipetting should be done within a half minute after the milk is thoroughly mixed. A sample partly churned should not be tested, because it is impossible to obtain accurate results. When a churned sample must be tested, however, it should be warmed to a temperature of 110° F., thoroughly mixed, and rapidly pipetted before the milk comes to rest. It is very important to pipette this sample rapidly, as the fat is melted and rises very quickly.

**Reagents.**[2]—The reagents are commercial concentrated sulphuric

[2] Taken in part from Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, 1925 edition.

acid with a specific gravity of 1.82–1.83 at 20° C., and water. Soft water is preferable, but hard water may be used if a few drops of acid are added.

**Apparatus.**[3]

*Test Bottle.*—The standard Babcock test bottle for milk shall be as follows:

*Eight per cent,* 18-*gram,* 6-*inch milk test bottle.*—The total height of this bottle shall be 150–165 mm. (5.9–6.5 inches). The bottom shall be flat, and the axis of the neck shall be vertical when the bottle stands on a level surface. The charge of milk for the bottle shall be 18 grams.

*Courtesy Creamery Package Mfg. Co.*

FIG. 70. FIG. 71.

FIG. 70.—Eight Per Cent, 18-gram, 6-inch Milk Test Bottle.

FIG. 71.—Standard Milk Pipette. Calibrated to Contain 17.6 c.c.

The capacity of the bulb to the junction with the neck shall be not less than 45 c.c. The shape of the bulb shall be either cylindrical or conical. If cylindrical, the outside diameter shall be between 34 and 36 mm.; if conical, the outside diameter of the base shall be between 31 and 33 mm., and the maximum diameter between 35 and 37 mm.

The neck shall be cylindrical and of uniform diameter from at least 5 mm. below the lowest graduation mark to at least 5 mm. above the highest. The top of the neck shall be flared to a diameter of not less than 10 mm. The graduated portion of the neck shall have a length of not less than 63.5 mm. The total per cent graduation shall be 8. The graduations shall represent whole per cent, five-tenths per cent, and one-tenth per cent, respectively, from 0.0 to 8.0 per cent. The tenths per cent graduations shall be not less than 3 mm. in length; the five-tenths per cent graduations shall be not less than 4 mm. in length and shall project 1 mm. to the left; and the whole per cent graduations shall extend at least half-way around the neck to the right and shall project at least 2 mm. to the left of the tenths per cent graduations. Each whole per cent graduation shall be numbered, the number being placed to the left of the scale. The

[3] Taken in part from Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, 1925 edition.

capacity of the neck for each whole per cent on the scale shall be 0.20 c.c. The maximum error of the total graduation or any part thereof shall not exceed the volume of the smallest unit of the graduation.

Each bottle shall be so constructed as to withstand the stress to which it will be subjected in the centrifuge.

*Pipette.*—The standard milk pipette shall conform to the following specifications:

Total length: not more than 330 mm.
Outside diameter of suction tube: 6–8 mm.
Length of suction tube: 130 mm.
Outside diameter of delivery tube: 4.5–5.5 mm.
Length of delivery tube: 100–120 mm.
Distance of graduation mark above bulb: 15–45 mm.
Nozzle: straight.
Graduation: to contain 17.6 c.c. of water at 20° C., when the bottom of the meniscus coincides with the mark on the suction tube.
Delivery in 5–8 seconds.
The maximum error in the graduation shall not exceed 0.05 c.c.
The pipette is to be marked "Holds 17.6 cc."

*Acid Measure.*—The device employed to measure sulphuric acid, whether a graduated cylinder or a pipette attached to a Swedish acid bottle, shall be graduated to deliver 17.5 c.c.

*Centrifuge or "Tester."*—The standard centrifuge, however driven, shall be constructed throughout and so mounted as to be capable, when filled to capacity, of rotating at the necessary speed with a minimum of vibration and without liability of causing injury or accident. It shall be heated, electrically or otherwise, to a temperature of at last 55° C., (130° F.) during the process of centrifuging. It shall be provided with a speed indicator, permanently attached, if possible. The proper rate of rotation may be ascertained by reference to the table below. By "diameter of wheel" is meant the distance between the inside bottoms of opposite cups measured through the center of rotation of the centrifuge wheel while the cups are horizontally extended.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Diameter of wheel, in inches..... | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| Number revolutions per minute.. | 1074 | 980 | 909 | 848 | 800 | 759 | 724 | 693 |

*Dividers or Calipers.*—Dividers or calipers are used for measuring the fat column.

*Water Bath for Test Bottles.*—The water bath for test bottles shall be provided with a thermometer and a device for maintaining a temperature of 55–60° C. (130–140° F.). The water must always come up to the top of the fat column.

**Procedure.**—A pipette full of the prepared sample is measured into a test bottle, care being taken to have the top of the meniscus of milk coincide exactly with the graduation on the pipette. The tip of the pipette is inserted into the neck of a clean test bottle, allowed to drain from five to eight seconds, and the drop that collects at the tip is blown out. While the test bottle is being rotated, 17.5 c.c. of sulphuric acid, having a temperature of about 60° F., is added, so as to wash down any milk that may be on the sides of the neck. The acid and milk are mixed by a smooth circular motion until a uniform color is obtained. The test bottles are placed in the centrifuge, and are counterbalanced and whirled for five minutes at the proper speed. Water at a temperature of 60° C. (140° F.), or hotter, is added to fill the test bottle to the bottom of the neck. After centrifuging again for two minutes at the proper speed, water is added (140° F., or hotter) to fill to the 7 per cent mark. One more minute of centrifuging at the proper speed and the test bottle is transferred to a water bath maintained at 130–140° F., being immersed to the level of the top of the fat column. It should be left for not less than ten minutes.

The bottle is removed from the bath and, with the aid of dividers or calipers, the fat column is measured from its lower surface to the top of the upper meniscus. Without being changed, the dividers are then placed on the scale and the percentage of fat is read directly.

The fat column, at the time of measurement, should be translucent, of a golden yellow or amber color, and free from visible suspended particles. All tests in which the fat column is milky or shows the presence of curd or of charred matter, or in which the reading is indistinct or uncertain, should be rejected.

Test bottles are emptied immediately by shaking vigorously to remove the sediment in the bottom. They should be thoroughly cleaned with a solution of washing compound and a brush. The washing solution is emptied out, and the bottles rinsed twice with about 20 c.c. of clean, warm water each time.

**Precautions for Babcock Test:**

1. Have sample thoroughly mixed, smooth, and uniform.
2. Have milk and acid at 60–80° F. (16 to 21° C.).
3. Measure milk accurately, being careful to get full measure into bottle.
4. Have test bottles clean—free from milk and fat or grease.

5. Mix milk and acid as soon as possible after adding acid, because allowing to stand at this time may result in charred material in the fat column.
6. Mix acid and milk with smooth rotary motion.
7. Have the temperature of the mixture at least 140° F. while it is being centrifuged.
8. Keep the centrifuge balanced, oiled, warm, and run at the proper speed.
9. Have water bath come to top of fat column.
10. Read tests immediately after removing from water bath.
11. Read tests correctly and closely. Be careful not to over-read or under-read. Read to nearest tenth of a per cent.
12. Have all fat columns the proper color and supported by a clear liquid.
13. Handle acid carefully. If any is spilled, wash up immediately with plenty of plain water and then with dilute alkali.
14. Clean equipment immediately after using.

This procedure agrees with that accepted by the Association of Official Agricultural Chemists and should give very accurate results for commercial conditions.

### *Cream*

In taking samples of cream, it should be remembered that cream is more viscous and carries a greater proportion of fat than does milk, making it more difficult to secure a homogeneous emulsion. It is frequently advisable to warm the cream to 90–100° F. to facilitate mixing. When handling samples, great care should be used to prevent churning. Composite samples of cream should never be taken. Otherwise, the directions given for sampling milk should be followed.

**Preparation of Sample.**—A sample to be tested in the laboratory should be warmed to 100–110° F. (38 to 43° C.) before mixing. "Oiling off," which occurs when the sample is over-heated or allowed to stand too long at a temperature of 110° F., should be avoided. After the cream is warmed, it should be thoroughly mixed and all lumps broken up. A wide-mouthed 9-c.c. pipette is convenient for transferring the sample to the test bottle.

**Reagents.**[4]—The reagents are commercial concentrated sulphuric acid, with a specific gravity of 1.82–1.83 at 20° C., and glymol, or clear white mineral oil, with a specific gravity not to exceed 0.85 at 20° C. Oil-

[4] Taken in part from Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, 1925 edition.

soluble artificial color may be added to the oil. A good method of coloring is to wrap an ounce of the powdered alkanet root in a piece of cheese cloth and allow it to soak about twenty-four hours in a quart of the oil. Another method[5] involves the use of an aniline dye, which is put in a solution by making a paste of the required quantity of oil, about 1 gram to the gallon. Heating causes it to go into solution more quickly. The remainder of the oil is added and the entire quantity strained through cheese cloth. This procedure should not require over ten or fifteen minutes.

*Water.*—Soft water is preferable, but hard water may be used if a few drops of acid are added.

**Apparatus.**[6]

*Test Bottle.*—The standard Babcock test bottle for cream shall be as follows:

(1) *Fifty per cent, 9-gram, short-neck, 6-inch cream-test bottle.*—The total height of the bottle shall be 150–165 mm. (5.9–6.5 inches). The bottom shall be flat, and the axis of the neck shall be vertical when the bottle stands on a level surface. The charge of cream for the bottle shall be 9 grams.

The capacity of the bulb to the junction with the neck shall be not less than 45 c.c. The shape of the bulb shall be either cylindrical or conical. If cylindrical, the outside diameter shall be between 34 and 36 mm.; if conical, the outside diameter of the base shall be between 31 and 33 mm., and the maximum diameter between 36 and 37 mm.

The neck shall be cylindrical and of uniform diameter from at least 5 mm. below the lowest graduation mark to at least 5 mm. above the highest. The top of the neck shall be flared to a diameter of not less than 15 mm. The graduated portion of the neck shall have a length of not less than 63.5 mm. The total per cent graduation shall be 50. The graduations shall represent five per cent, one per cent, and one-half per cent, respectively, from 0.0 to 50 per cent. The five per cent graduations shall extend at least half-way around the neck to the right; the one-half per cent graduations shall be not less than 3 mm. in length; and the one per cent graduations shall be intermediate in length between the five per cent and the one-half per cent graduations and shall project 2 mm. to the left of the one-half per cent graduations. Each five per

[5] Either New Port Oil Red No. 13044, sold by the New Port Chemical Works, Passaic, New Jersey, or National Oil Red 0, sold by the National Aniline and Chemical Company, 357 West Erie Street, Chicago, Illinois, can be used.

[6] Taken in part from Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, 1925 edition.

cent graduation shall be numbered (thus: 0, 5, 10, . . . 45, 50), the number being placed to the left of the scale. The capacity of the neck for each whole per cent on the scale shall be 0.1 c.c. The maximum error in the total graduation or any part thereof shall not exceed the volume of the smallest unit of the graduation.

(2) *Fifty per cent, 9-gram, long-neck, 9-inch cream-test bottle.*—The same specifications shall apply to this bottle as to the 50 per cent, 9-gram, 6-inch cream-test bottle, with the exceptions, however, that the total height of this bottle shall be 210–229 mm. (8.25–9.0 inches) and that the graduated portion of the neck shall have a length of not less than 120 mm.

(3) *Fifty per cent, 18-gram, long-neck, 9-inch cream-test bottle.*—The same specifications shall apply to this bottle as to the 50 per cent, 9-gram, 9-inch cream-test bottle, with the exception, however, that the charge of cream for this bottle shall be 18 grams.

Each bottle shall bear on the top of the neck above the graduations, in plain, legible characters, a mark denoting the weight of the charge to be used, viz., "9 gram" or "18 gram," as the case may be.

Each bottle shall be so constructed as to withstand the stress to which it will be subjected in the centrifuge.

*Water Bath for Cream Samples.*—The water bath shall be provided with a thermometer and a device for maintaining a temperature of 38 to 50° C. (100–122° F.).

*Cream-weighing Scales.*—The standard cream-weighing scales shall have a sensibility reciprocal of 30 mg., i.e., the addition of 30 mg. to either pan of the scale, when loaded to capacity, shall cause a deflection of at least one subdivision of the graduation. The scales shall be set level upon the table support and be protected from drafts. With a little care, it is possible to use butter moisture scales in place of cream scales, but they must have the same sensibility and accuracy.

*Weights.*—The standard cream-test weights shall be 9 grams and 18 grams, respectively, and shall be plainly marked "9 gram," or "18 gram," as the case may be. They shall be made of material capable of resisting corrosion or other injury; shall preferably be of a low, squat shape, with rounded edges, and shall be verified at frequent intervals by comparison with standardized weights.

*Acid Measure*
*Centrifuge or "Tester"*
*Dividers or Calipers*
*Water Bath for Test Bottles*
} Described under Milk.

*Pipette.*—A wide-mouthed 9-c.c. pipette may be used to handle cream.

**Procedure.**—The outside of the test bottles should be dried and labeled. They are placed on the scales and, by means of the tare weight on the scales, accurately balanced. Nine grams of the prepared sample are weighed into a 9-gram cream-test bottle, or 18 grams into an 18-gram cream-test bottle, the procedure then being as given in one of the following methods:

*Method* 1.—After the cream has been weighed into the test bottle, 8–12 c.c. of the sulphuric acid is added, in the case of the 9-gram bottle, or 14–17 c.c. in the case of the 18-gram bottle; or acid is added until the mixture of cream and acid, after shaking, has assumed a chocolate-brown color. The bottle is shaken with a rotary motion until all lumps have completely disappeared; then 5–10 c.c. of water is added at 140° F., (60° C.) or hotter. This water stops the action of the acid and tends to prevent charring. The bottle is transferred to the centrifuge, counter-balanced, and, after the proper speed has been attained, whirled for five minutes. Hot water is added until the liquid column approaches the top graduation of the scale; the bottles are then whirled one minute longer. They are transferred to the water bath, maintained at 55–60° C. (130–140° F.), where they are immersed to the level of the top of the fat column and left for not less than ten minutes. Two or three drops of glymol are placed on the surface of the fat column. Care should be taken to allow the glymol to run down the side of the neck in order to prevent its splashing and getting beneath the fat column. The bottles are removed from the bath, and, with the aid of dividers or calipers, the fat column is measured from its lowest surface to the line of division between the fat column and the glymol. Without changing, the dividers are placed on the scale and the percentage of fat is read directly.

*Method* 2. (*For a* 9-*gram bottle only*).—After the cream has been weighed into the test bottle, 9 c.c. of soft water is added at 140° F. or hotter, and thoroughly mixed; 17.5 c.c. of the sulphuric acid is added and shaken with a rotary motion until all lumps have completely disappeared. The bottles are transferred to the centrifuge, are counter-balanced, and, after the proper speed has been attained, are whirled for five minutes. The bottle is filled to the neck with hot water and whirled for two minutes. Hot water is added until the liquid column approaches the top graduation of the scale. The whirling is continued for one minute longer. The procedure from this point is the same as that given under Method 1.

Whichever method is followed, the fat column, at the time of reading, should be translucent, of a golden-yellow to amber color, and free from visible suspended particles. All tests in which the fat column is

milky or shows the presence of curd or of charred matter, or in which the reading is indistinct or uncertain, should be rejected.

**Precautions for Babcock Test.**—Since good results are hard to obtain when testing cream, the following precautions should be observed:

1. Have sample thoroughly mixed, smooth, and uniform.
2. In weighing cream, be sure to get it *all* inside of the bottle, as any on the outside will weigh just the same.
3. Have cream scales clean, free from dust or cream, and protected from drafts.
4. Balance cream scales in motion (have the pointer swing as far on one side of the center as it does on the other) instead of allowing the pointer to come to rest at the center.
5. Have test bottles clean, free from milk and fat or grease.
6. Have mixture at a temperature of at least 140° F. while being centrifuged.
7. Keep centrifuge balanced, oiled, and warm, and run it at the proper speed.
8. Have water bath come to top of fat column.
9. Read tests immediately after removing from water bath.
10. Read tests correctly and closely. Be careful not to over-read or under-read. Read to nearest five-tenths of a per cent.
11. Use glymol in reading *all* tests made in cream-test bottles.
12. Have all fat columns the proper color and supported by a clear liquid.

### *Skim Milk* [7]

Skim milk is somewhat difficult to test because it contains only the small, finely divided fat globules which were not removed by the centrifugal force of separation and which are hard to gather in the tube for measure. In sampling skim-milk and preparing the sample for testing, the directions given for milk should be followed exactly.

**Reagents.**—The same reagents are used for testing skim-milk as were described in the testing of whole milk.

**Apparatus:**

*Test Bottles.*—These should have two necks; one of large diameter, which reaches nearly to the bottom of the bulb through which the milk and acid are added; and one of small bore, in which the fat is collected and measured. The small neck should have a total graduation of 0.50 per cent, the smallest graduation representing 0.01 per cent.

[7] See also the Normal Butyl Alcohol Method, p. 278.

*Pipette*
*Acid Measure*
*Centrifuge or "Tester"*
*Dividers or Calipers*
} Described under Milk.

**Procedure.**—A pipette full of properly prepared sample is measured into the test bottle. Twenty to 22 c.c. of sulphuric acid is added, preferably in two portions (about half at a time), each portion being thoroughly mixed as soon as added. If all the acid is added at one time, there is not room enough for thorough mixing and some of the curd may be splashed into the small neck.

When the acid is thoroughly mixed with the skim milk, the test bottle is placed in the centrifuge, care being taken to place the larger neck nearest the center of the machine. The machine is counterbalanced with other skim-milk test bottles. After ten minutes of centrifuging, the bottle is filled to the base of the neck with hot water (140° F. or hotter).

After whirling again for two minutes, the fat column is brought within the graduated portion of the neck with hot water. A final centrifuging of two minutes, and the test bottle is removed and read immediately, provided that the centrifuge is heated to 130° F. (55° C.) In recording the test the method used should be stated.

It is always advisable to use dividers in reading skim-milk tests. The fat column should be a clear amber color and should be supported by a light brown liquid free from sediment.

This method does not give an accurate test but has been so widely used that dairymen usually think in terms of it. For example, if skim milk tests 0.02 per cent by this method, it is considered to be efficiently skimmed, although a chemical analysis or a test by the Mojonnier Method would show about 0.10 per cent and the Normal Butyl Alcohol Method would show about 0.04–0.06 per cent.

**The Normal Butyl Alcohol Method.**—This method,[8] invented by Mitchell for testing buttermilk, is a modification of the Babcock method, and is being rapidly adopted for testing skim milk. It is sometimes referred to as the American Association Method. It is based on the fact that the normal butyl alcohol, by some mechanical effect, makes it possible to bring a larger number of the finely divided fat globules into the neck of the test bottle, thereby giving more nearly accurate results. Good, clear fat columns are more easily obtained in this method than in any other.

The sample should be taken and prepared as outlined on page 269.

[8] Mitchell, W. J., Churning losses, Chicago Dairy Produce, Dec. 13, 1921, pp. 16–19.

**Reagents.**—The reagents for the skim milk test are commercial concentrated sulphuric acid, with a specific gravity of 1.82–1.83 at 20° C.; normal butyl alcohol, which should be free from any oily particles (this is a poisonous solution and should be kept stoppered all the time); and water. While soft water is preferable, hard water may be used if a few drops of acid are added.

**Apparatus:**

*Test Bottles.*—These should have two necks: one of large diameter, which reaches nearly to the bottom of the bulb through which the milk and acid are added; and the other of small bore, in which the fat is collected and measured. The small neck should have a total graduation of 0.50 of 1 per cent, the smallest graduation representing 0.01 per cent.

*Courtesy Creamery Package Mfg. Co.*

FIG. 72.—Skim Milk Test Bottle

9-*c.c. Pipette.*
2-c.c. *Pipette*
*Acid Measure*
*Centrifuge or "Tester"*
*Dividers or Calipers*

} Described under milk.

**Procedure.**—Two cubic centimeters of the normal butyl alcohol are placed in the test bottle, and 9 c.c. of the properly prepared sample of skim milk are added. From 7 to 9 c.c. of sulphuric acid are added and thoroughly mixed, with a rotary motion. The bottle is placed in the centrifuge, with the large neck nearest the center of the machine, and counterbalanced. The bottle is centrifuged for six minutes at full speed and filled with hot water (temperature 140° F., or hotter) to the bottom of the neck. Two minutes more of centrifuging at full speed, and the bottle is removed from the centrifuge and read immediately if the machine is heated. If a cold machine is used the bottle should be placed in a water bath (temperature 130–140° F.) for five minutes before being read. The reading is multiplied by 2.

The method used should always be stated when the test on a sample of skim milk is being reported. The results obtained by this method are more accurate than those by the Babcock Method. A test of 0.04 to 0.06 per cent by the American Association Method is indicative of efficient separation.

*Evaporated Milk (Unsweetened Condensed)*

**Preparation of Sample.**—The can of evaporated milk should be shaken vigorously before opening. If small lumps of butter are found, the sample should be warmed to 130° F. before mixing. A thorough mixing is obtained by pouring from the can to a beaker four or five times, being careful to get all the cream from the corners and seams of the can. None of the contents of the can should be spilled until thoroughly mixed.

**Reagents.**—The reagents for testing evaporated milk are the same as those given under the tests for milk.

**Apparatus:**

*Analytical Balance.*—Butter moisture scale or cream scale may be used.

*Set of Weights.*

*Glass Beakers,* capacity approximately 250 c.c.

*Pipette*
*Milk-test Bottles*
*Acid Measure*
*Centrifuge or "Tester"*
*Dividers or Calipers*
*Water Bath for Test Bottles*
} Described under milk.

**Procedure.**—The sample is diluted with an equal weight of water. Nine grams of the diluted sample is weighed into a standard milk-test bottle, about 9 c.c. of water is added, and the mixture shaken. Seventeen and five-tenths c.c. of sulphuric acid is added and thoroughly mixed. The bottle is centrifuged for five minutes and then filled to the base of the neck with dilute sulphuric acid.[9] The procedure from this point is the same as for milk, except that the reading is multiplied by 4.

This method offers many possibilities for error. Furthermore, any error made in the test is multiplied by 4 in the final reading, which exaggerates the error that much more. It is therefore very important to exercise the greatest care in using this method. While the results obtained are not absolutely accurate, they are sufficiently accurate for standardizing a mix.

[9] This dilute sulphuric acid must be made up fresh and added while hot. Sulphuric acid, sp. gr. 1.82–1.83, is added to an equal amount of water in a beaker, thoroughly mixing after each small addition of acid.

### *Sweetened Condensed Milk*

Since sweetened condensed milk contains a large amount of sugar as well as milk solids-not-fat, and since sulphuric acid has a strong affinity for carbohydrates, it is necessary to use some means of reducing the sugar content.

**Preparation of Sample.**—The contents of the can are emptied into a mortar or bowl, and all sediment and lumps of sugar are carefully scraped from the corners or seams of the can. The sample is thoroughly mixed to a homogeneous mass with a pestle. This procedure is very important if a representative sample is to be obtained.

Exactly 40 grams are weighed into a 100-c.c. volumetric flask, which is filled to the mark with water. Complete solution is facilitated by adding water in several installments and shaking after each addition until the condensed milk no longer sticks to the sides of the flask. This mixture is referred to as a "prepared sample" in the following analyses.

**Reagents.**—The reagents for sweetened condensed are the same as for testing milk.

**Apparatus:**

100-*c.c. Volumetric Flask.*
*Mortar and Pestle.*
*Analytical Balance.* Butter moisture scale or cream scale may be used.
*Set of Weights*
*Glass Beakers,* capacity approximately 250 c.c.
*Pipette*
*Milk-test Bottle*
*Acid Measure*
*Centrifuge or "Tester"*
*Dividers or Calipers*
*Water Bath for Test Bottles*
} Described under milk.

**Procedure.**—Eighteen grams of the prepared sample are weighed into a standard milk-test bottle. Four cubic centimeters of sulphuric acid are added, and immediately the acid and milk are mixed and whirled for six minutes at full speed. The centrifuge is stopped slowly and the test bottle carefully removed so that the layer of curd is not broken up. The clear liquid is decanted without breaking up the curd. About 12 c.c. of water are added and shaken. Four cubic centimeters of sulphuric acid are added, thoroughly mixed, centrifuged, and decanted as before. Then about 17.5 c.c. of water are added and shaken. Seventeen and five-tenths cubic centimeters of sulphuric acid are added and thoroughly

mixed. The test is completed as for milk, except that the reading is multiplied by 2.5.

If the sweetened condensed milk contains less than 4 per cent fat, the curd may be so heavy that it will not float in the form of a firm cheese, thus making it difficult to decant a clear whey. Care must be exercised to lose no curd in the process, however.

### *Milk Powder*

**Preparation of Sample.**—The sample is thoroughly mixed with a spatula or spoon and all lumps, however small, are carefully broken up.

**Reagents.**—The reagents for the milk powder test are as follows: dilute sulphuric acid (395 c.c. sulphuric acid *poured into* 605 c.c. water and thoroughly mixed); commercial concentrated sulphuric acid, with a specific gravity of 1.82 to 1.83 at 20° C.; and water. Though soft water is preferable, hard water may be used if a few drops of acid are added.

**Apparatus:**

*Analytical Balance.*—Butter moisture scales may be used.
2.5-*gram Weight.*—If butter moisture scale is used, this weight may not be needed.[10]
*Graduated Cylinder,* capacity 50 c.c.
10-*gram Weight.*
*Small Funnel.*
*Milk-test Bottle*
*Acid Measure*
*Centrifuge or "Tester"*
*Dividers or Calipers*
*Water Bath for Test Bottles*
} Described under Milk.

**Procedure.**—*Method* 1.—Two-and-a-half grams of prepared sample are accurately weighed and transferred to a standard milk-test bottle, a small funnel being used to aid in making the transfer. Thirty-one cubic centimeters of dilute sulphuric acid are added and the bottle is placed in a hot water bath (temperature 212° F.) and shaken frequently till all the powder is in solution, usually ten minutes. The bottle is removed from the water bath, and 12 c.c. of sulphuric acid, with a specific gravity of 1.82 to 1.83 added. After mixing, the test is com-

[10] If butter moisture scale is used, the scales are balanced with a small piece of paper on the *left* hand pan, the riders being placed at zero. The latter are moved to indicate 25 per cent, and the scales are brought to exact balance by placing the prepared sample of powder on the paper. This gives exactly 2.5 grams of powder.

pleted as for milk, except that the fat is read to 0.05 per cent on the graduations and the reading multiplied by 7.2.

This method, devised by Redmond,[11] gives results that average about 0.13 per cent too high, though individual samples may be nearer the true test. Many opportunities for error are offered. Any error is greatly increased by multiplying the reading by such a large factor (7.2). This is probably the best commercial method to use, however, unless the Mojonnier Method is available.

*Method* 2.—Exactly 10 grams of the prepared sample are weighed into a 100-c.c. beaker and dissolved in a small amount of warm water. None of the powder should be lost. When a complete solution is effected, the sample is poured into a 100-c.c. volumetric flask, the beaker is rinsed clean, and the rinsings are added to the flask. It is very important to get all of the milk powder solution into the 100-c.c. flask before diluting it to 100 c.c. volume. Otherwise, the results will be too low. Water is added to fill the flask exactly to the mark. Then the procedure is the same as directed for milk on page 272. The reading is multiplied by 10 to get the percentage of fat in the powder.

This method is subject to the same criticism as Method 1 except that errors in this case are multiplied by a larger factor (10). The main advantage of Method 2 is that there is less danger of the sulphuric acid's charring the powder.

### *Ice Cream*

Ice cream is very difficult to test because of the high concentration of milk solids-not-fat and the high sugar content. Since it is practically impossible to obtain good results with sulphuric acid, a modification of the Babcock Method is generally used.

As it is quite difficult to prepare a sample of ice cream for testing, the manufacturer should test the unfrozen mix instead of the frozen product. In either case, it is important to get a representative sample thoroughly mixed into a smooth homogeneous emulsion. A sample of ice cream is prepared by the same method used for the ordinary cream sample.

**Reagents.**—The reagents for the ice cream test are as follows: Commercial concentrated sulphuric acid, with a specific gravity of 1.82–1.83 at 20° C.; 80 per cent glacial acetic acid made by diluting 80 c.c. of chemically pure concentrated glacial acetic acid to 100 c.c. with distilled water (it is advisable to make up a fresh supply every four to six months as old glacial acetic acid may give high results); mixed acid,

[11] A modification of the Babcock Test as applied to the estimation of fat in desiccated milk; Redmond, Jour. Ind. and Eng. Chem. Vol. 4, p. 544, 1912.

consisting of equal parts of concentrated hydrochloric acid and concentrated glacial acetic acid mixed together and allowed to stand over night before using. (This solution should not be more than four to six months old.)

**Apparatus:**

*Cream Scales* }
*9-gram Weight* } Described under testing cream.

9-gram cream-test bottles may be used, but the results will not be as accurate, because the test bottles are not as finely graduated.

*Pipette.* A wide-mouthed 9-c.c. pipette may be found more convenient than the 17.6 c.c. pipette used in testing milk.

*Graduated Cylinder*, with a capacity of 50 c.c.

*Acid Measure* }
*Centrifuge or "Tester"* }
*Dividers or Calipers* } Described under Milk.
*Water Bath for Test Bottles* }

**Procedure.**—The outsides of the test bottles are dried and labeled. They are placed on the scales, and, by means of the tare weight on the scales, accurately balanced. Nine grams of the prepared sample are weighed into the test bottle, and one of the methods given below is followed.

*Method* 1.—*Glacial acetic-sulphuric acid test.*—After the ice cream has been weighed into the test bottle, 17.5 c.c. of 80 per cent glacial acetic acid are added and thoroughly mixed. About the same amount of sulphuric acid is added and thoroughly mixed. The bottles are now ready to be centrifuged and the test completed as for milk. If the standard milk-test bottle is used, the reading must be multiplied by 2 to give the correct test of the ice cream. The 9-gram cream-test bottle will read directly in per cent.

The fat columns should have the same appearance as those of milk being tested. Difficulties can usually be overcome by varying the amount of sulphuric acid added.

*Method* 2.—*Glacial acetic-hydrochloric acid test.*—After the ice cream has been weighed into the test bottle, 25–30 c.c. of the mixed acid are added, mixed thoroughly, and allowed to stand a minute. Then it is thoroughly mixed again. Great care must be used to dissolve the ice cream completely. Hurrying at this point may cause poor tests. The bottle is then transferred to a boiling water bath and is shaken occasionally while heating, until a chocolate-brown color has developed. It is

placed in the centrifuge, and the test completed as for milk. If the standard milk-test bottle is used, the reading is multiplied by 2 to get the correct test of the ice cream. If the 9-gram cream-test bottle is used, the correct test may be read directly.

The fat columns should have the same appearance as those of milk being tested.

*The Fucoma Method.*—This method, originally invented by Dr. Gerber, is the same as the Gerber Method, which is used almost universally in Europe. For a long time it received little publicity in this country, because all the apparatus is manufactured in Germany, the glassware being blown by hand. With the recent establishment of supply houses in this country, the apparatus has become easily obtainable. The Fucoma Method depends upon the sulphuric acid to dissolve the milk solids-not-fat and, with the aid of amyl alcohol, to liberate the fat so that centrifugal force can bring it into a graduated tube for measuring.

The apparatus differs from the Babcock in that the test bottles are laid horizontally in the centrifuge instead of being set in hinged sockets. This makes it necessary to close the top, or small end, of the bottle. The neck, or graduated portion, is a flat tube, and the bottom is fitted with a rubber stopper.

Though this method is easy to learn and operate, some difficulty is experienced by the average commercial tester keeping the bottles clean. If samples are preserved with corrosive sublimate, the results obtained may be inaccurate.

**Preparation of Sample.**—The sample should be taken and prepared for testing exactly as outlined on page 273.

**Reagents.**—The reagents for the ice cream test are as follows: Commercial sulphuric acid (87 : 13, that is, 87 parts of sulphuric acid, with a specific gravity of 1.82–1.83, and 13 parts of water) (use this for vanilla or plain ice cream); commercial sulphuric acid (94 : 6, that is, 94 parts of sulphuric acid, with a specific gravity of 1.82–1.83, and 6 parts of water) (use this for chocolate, fruit, or nut ice cream); chemically pure amyl alcohol, with a specific gravity of 0.815–0.818 at 15° C. and a boiling point of 128–130° C. (It must be free from oily particles. It should be well-stoppered because of its strong odor, and should be kept preferably in a dark place, as light tends to change its color slightly to brown.)

**Apparatus:**

*Centrifuge,* equipped with speed indicator and heater

*Ice Cream Test Bottles,* graduated to 15 per cent in tenths of a per cent with supply of rubber stoppers

*Acid Measure,* graduated for 10 c.c.

5-*c.c. Pipette*

1-*c.c. Pipette,* with bulb to protect against getting amyl alcohol into mouth

*Scales for Weighing Sample,* together with rack to support test bottle while being weighed

5-*gram Weight*

*Water Bath,* with thermometer and a device to maintain temperature at 130–140° F. (55–60° C.)

**Procedure.**—Ten cubic centimeters of commercial sulphuric acid are poured into a test bottle (the strength of the acid depending on the kind of ice cream being tested). The bottle is placed on scales and balanced by a tare weight. Exactly 5 grams of the properly prepared sample are weighed into the test bottle, allowing it to form a layer on top of the acid, with a colorless line between the layers. Care must be taken not to mix the ice cream with the acid at this time, as it will cause charring. The sides of the mouth of the bottle where the stopper fits must be kept perfectly dry. If too much ice cream is placed in the bottle, precautions must be taken not to remove any of the acid. Five cubic centimeters of cold water and 1 c.c. of amyl alcohol are carefully added. The rubber stopper is screwed into place, usually until the small end of the stopper protrudes nearly $\frac{1}{8}$ inch into the bulb. The mouth of the test bottle and the rubber stopper should be held close to each other, and then, with a twisting motion, screwed together. This trick will eliminate much difficulty and breakage. The stoppers should be dry and soft so that they work smoothly, not jerkily.

The ice cream and acid are thoroughly mixed by shaking and inverting the test bottle. When a uniform color is obtained, the bottle is placed in the centrifuge and whirled at not less than 850 r.p.m. for four minutes. The test bottle is removed from the centrifuge and placed in the water bath, the temperature being held at 130–140° F. for ten minutes. The bottle is removed from the water bath and read immediately, by adjusting the rubber stopper so that the bottom of the fat column coincides with the zero mark, and the percentage of fat is read at the bottom of the upper meniscus. It is not necessary to use dividers. If for any reason the stopper moves with a jerky motion, it will splash some of the fat up into the top of the bottle. This will make it necessary to centrifuge the bottle again and repeat the water bath before reading.

The test bottle is emptied by removing the rubber stopper and shaking. The test bottles are washed with a cleaning solution and

rinsed at least twice with clean, fresh water. The graduated neck must be kept clean.

If reasonable care is used in following these directions, a good clear fat column, free from any sediment, is easily obtained. The results are found to be very accurate.

### *Butter*

**Kohman Method.**[12]—This method, commonly referred to as the Gasoline Extraction Method, is used for determining the fat content of butter and butter oil. It is based upon the fact that butterfat is soluble in ether or high-test gasoline, while the other constituents of butter are insoluble and rapidly settle to the bottom, thereby allowing the ether-fat (or gasoline-fat) solution to be poured off. With proper care this method will give results that check within 0.1 per cent of the Mojonnier. It is a rapid, inexpensive, and very accurate method for commercial conditions. It has the advantage of giving a complete analysis of the butter or butter oil without requiring more than one sample to be weighed. Only the directions for the fat determination will be given. For the other parts of this method, see pages 290, 303.

To test butter, it is necessary to obtain an accurate, representative sample. This is done by drawing several plugs, each one extending from the top to the bottom of the container, from different places in the container. These plugs are all put into the same clean, dry, sample bottle,[13] carefully stoppered to prevent evaporation and adulteration, correctly labeled, and kept in a cool place until ready for testing.

**Preparation of Sample.**—The sample should be placed in a water bath (*no hotter* than 95–100° F.) and stirred with a spatula to a smooth, homogeneous emulsion about the consistency of thick cream. It will have the same color as the original butter and will be just soft enough to lose its shape. It must not be melted, for if this is done the water will settle out, thus making it impossible to get a representative sample. If the sample should become melted it may be cooled to the proper consistency and thoroughly mixed, though this is not recommended. In the softened condition, it can be handled easily with a spatula or wide-mouthed pipette.

**Reagents.**—The reagents for the butter test are petroleum ether, which must be free from fat or oily particles, and hot distilled water. High-test gasoline may be substituted for ether, but the same precautions and method must be used.

[12] A rapid and accurate method for butter analysis, suitable for factory control work; Kohman, Jour. Ind. and Eng. Chem., Vol. 11, No. 1, 1919.

[13] For detailed discussion of sample bottles, see p. 267.

**Apparatus.**—

*Torsion Butter Moisture Balance.*

10-*gram Weight.*

1-*gram Weight.*

*Aluminum Cup.*—Fairly tall and narrow, with lip and a capacity of approximately 100 c.c.

*Alcohol Lamp.*—A Bunsen burner may be used if turned very low. An electric hot plate controlled by a rheostat can also be used

*Pair of Tongs.*

*Spatulas.*

*Sample Bottles.*

*Glass Stirring Rod.*

**Procedure.**—To the residue remaining after all the moisture is evaporated from a 10-gram sample, as outlined on page 290, about 25–35 c.c. of high-test gasoline or petroleum ether are added. The ether should wash down the sides of the cup to remove the fat. The sample is thoroughly mixed by a rotary motion until the curd and fat are in solution. A glass rod may be used to mix the ether with the sample. It must be carefully washed with fresh ether before being removed from the cup, however, to prevent its carrying away any of the salt and curd. The sample is allowed to stand undisturbed in a tilted position so that the curd will settle in one corner of the cup. During this time, the casein, albumin, ash, sugar, and salt, which are insoluble in the ether, will settle to the bottom of the cup. The ether-fat solution is carefully decanted without allowing any of the residue to escape. This operation is repeated until the last washing comes off clear, showing that all the fat has been extracted. Three washings will usually be sufficient. Though the first washing[14] cannot be used again, the second and third may be saved for the first washing of the next sample. The decantate is heated slowly over a hot plate or low flame until the last traces of gas or ether are evaporated. Unless care is used in this operation, the contents will explode. If any of the residue is blown out of the cup, the results will be inaccurate and the samples should be started over again. As it dries, the residue changes gradually from a brown to a very light buff color. It should then be powder-like. The cup is cooled and weighed on butter-moisture scale, by substituting the 1-gram weight for the 10-gram weight and sliding the rider on the lower scale beam to the left-hand end. If the sediment weighed 1 gram, it would compose 10 per cent of the original 10-gram sample of butter. The 1-gram

[14] If desired, most of the ether can be recovered by distillation.

weight, therefore, is regarded as a 10 per cent weight. But, as the sediment weighs less than 1 gram, the scales must be balanced by means of the rider on the upper scale beam. This reading is taken to two decimal places and subtracted from 10 per cent. The result gives the percentage salt and curd.

The percentage of fat in the original sample is then obtained by the following formula:

$$100 \text{ per cent} - 19.55 \text{ per cent (moisture, salt, and curd)} = 80.45 \text{ per cent fat.}$$

The Shaw Test,[15] which gives very accurate results, may be used for determining the fat content of butter. Its main disadvantages are two: (1) it uses more butter per test; (2) it does not allow a complete analysis when a single sample only is weighed. Its advantage lies in allowing the sample to be saved for use in the next mix.

## METHODS OF ANALYSIS FOR TOTAL SOLIDS

The term "total solids" refers to the moisture-free constituents of the product or, in other words, the residue obtained by evaporating all the moisture. There are no rapid methods for accurately determining the total solids of dairy products. In every case the sample must be carefully weighed, the moisture evaporated without burning the solids, and the residue weighed. Special forms of hydrometers, however, are sometimes used to determine the approximate total solids of milk, condensed skim milk, and sweetened condensed skim milk.

Samples to be tested for total solids should be representative, thoroughly mixed, and free of preservatives.

**Mojonnier Method.**—This, the most rapid and accurate method of determining total solids, may be used on all dairy products. A specially constructed Mojonnier Tester is required. It is furnished with complete instructions,[16] thus making it unnecessary to repeat them here. The test consists of accurately weighing a very small sample, evaporating the excess moisture on a hot place, removing the last traces of moisture in a vacuum oven, cooling, and weighing the residue. The equipment is expensive to install and requires a very careful and highly trained operator.

**Irish Moisture Test.**—This method is used to determine the moisture content of butter and butter oil. It is the first step in the Kohman

[15] Shaw, R. H., Bureau of Animal Industry, Circ. 202, U. S. D. A., 1912.

[16] Also given in "The Technical Control of Dairy Products," by Mojonnier and Troy, published by Mojonnier Brothers.

Method of analyzing butter. It depends on heating a weighed sample of butter over a flame until all moisture is driven off, with subsequent cooling and weighing, the loss in weight representing the moisture driven off.

A butter sample must be accurately representative. Such a sample is obtained by drawing several plugs, preferably extending from the top to the bottom of the container. These plugs are all put into the same clean, dry sample bottle, carefully stoppered to prevent evaporation and adulteration, correctly labeled, and kept in a cool place until ready for testing.

**Apparatus:**

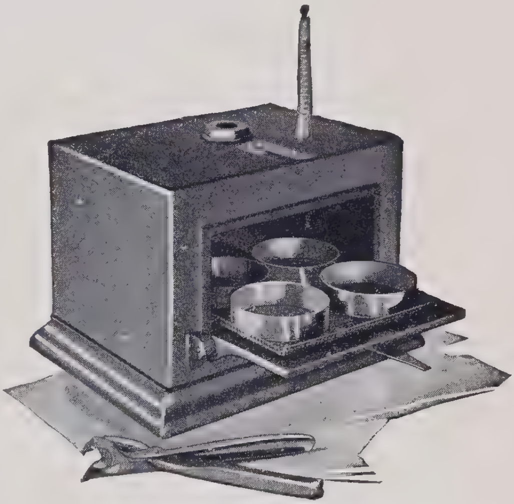
*Torsion Butter Moisture Balance.*
10-*gram Weight.*
*Aluminum Cup.*—Fairly tall and narrow with a lip. Capacity, about 100 c.c.
*Alcohol Lamp.*—A Bunsen burner may be used if turned very low. An electric hot plate with a rheostat may also be used.
*Pair of Tongs.*
*Spatulas.*
*Sample Bottles.*

**Procedure.**—The aluminum cup is thoroughly dried and cleaned. It should not be touched with the hands until after the sample is weighed in. The empty cup is placed on the right-hand pan of the moisture scales and balanced by means of the tare weight. The riders on the two scale beams should be at zero. The 10-gram weight is placed on the left-hand pan of the scales and exactly 10 grams of the butter are weighed into the cup. The sample is heated over a low flame or on a hot plate, to expel the moisture. The object is to keep the temperature of the sample around 240° F. (116° C.). This can be done by occasionally removing the cup from the flame. The cup is agitated gently during the heating process. The operator should be careful not to spill or to remove any of the fat with the tongs. Toward the end of the process, heat is applied slowly to avoid burning the fat and to aid in destroying the foam. A reddish-brown color assumed by the sediment indicates the point at which the heat should be removed. The fat should be a clear yellow on top of the reddish sediment. A mirror held over the top will remain clear and dry if all moisture has been driven off. After the cup has cooled it should be placed on the right-hand pan of the scales, the 10-gram weight being left on the left-hand pan. The rider on the lower beam of the scales is placed at the 10 per cent mark. The scales are balanced with the rider on the upper beam. The percentage

of moisture in the butter is found by adding together the readings on these two beams. To obtain the percentage of total solids, the per cent of moisture is subtracted from 100 per cent.

This method gives the percentage of moisture (or solids) only to 0.1 per cent, which is accurate enough for commercial uses of butter and butter oil. When carefully operated this method will not vary more than 0.1 per cent from the Mojonnier Method.

**Farrington Oven Method.**—For evaporating the moisture, this method depends upon the use of the Farrington High-pressure Oven, which is steam-jacketed and is connected directly with the boiler. With a steam pressure of 60 lbs. a temperature of 280° F. (138° C.) can be obtained. It is advisable to have the oven equipped with a thermometer rather than a pressure gage.



*Courtesy Creamery Package Mfg. Co.*

FIG. 73.—Farrington Oven for the Determination of Total Solids.

The advantages of this method are the low cost of its installation and the sturdiness of the apparatus, which is not likely to be injured by an unskilled operator. The disadvantages are the lower degree of accuracy and the small number of samples that can be handled at a time. The accuracy of the Farrington Oven Method depends upon the weighing. If analytical balances are used and weighings made to the fourth decimal, it is possible to get results accurate to 0.01 per cent. For commercial purposes, speed is usually more important than a high degree of accuracy, so results are computed to the hundredth place and considered accurate only to ± 0.1 per cent. Consequently, a butter moisture scale may be used in place of the analytical balance. Other advantages of using the butter moisture scale are speeding up the work, decreasing the cost of equipping the laboratory, and giving the average laboratory worker equipment with which he is familiar. It must be remembered, however, that such results may not be accurate.

In the following directions, it is recommended to use an oven temper-

ature of 212° F. and to heat the sample until there is no further loss in weight. This is a very slow and tedious process, but it allows the least possibility for error. Higher temperatures for shorter periods of time can be used with the proper care and technique, but there is danger of volatilizing constituents other than water.

### *Milk and Skim Milk*

**Preparation of sample.**—The sample, which should be taken and prepared as directed on pages 269, 277, should contain no preservative.

**Apparatus:**

*Butter Moisture Scales or Analytical Balance*
*Set of Weights and Fractional Weights*
*Flat Aluminum Dish.*—Not less than 5 cm. diameter, preferably with lid
*Tongs for Handling Dishes*
5-*c.c. Pipette*
*Desiccator*
*Farrington Oven with Thermometer*

**Procedure.**—A clean aluminum dish is heated in the oven at 212° F. for one-half hour, cooled in the desiccator, and tared. Tongs should always be used for handling the aluminum dish. Five cubic centimeters of the prepared sample are placed in the tared dish, and accurately weighed. The dish and sample are heated at a temperature of 212° F. until weight ceases to be lost. They are then cooled in a desiccator and weighed rapidly. The percentage of total solids is calculated from the following formula:

$$\frac{\text{Weight of dried sample}}{\text{Weight of sample}} \times 100 = \text{per cent total solids}$$

The lid should be on the dish while the weight is taken, but should be placed beside the dish in the oven and desiccator so as to allow the moisture to escape.

### *Evaporated Milk*

**Preparation of Sample.**—The sample is taken and prepared as directed on page 280.

**Apparatus.**—For testing milk, the apparatus specified above is used.

**Procedure.**—A clean aluminum dish is heated in the oven at 212° F. for one-half hour, cooled in the desiccator, and tared. It should be handled only with tongs. About 1 gram of the prepared sample is

accurately weighed into the dish. About 4 c.c. of water (temperature 120° F.) are added and thoroughly mixed by a gentle rotary motion. A stirring rod cannot be used as some of the sample may adhere to it. The test is completed as for milk by the Farrington High-pressure Oven Method.

*Sweetened Condensed Milk*

**Preparation of Sample.**—The sample is taken and prepared as directed on page 281.

**Apparatus:**

*Butter Moisture Scales or Analytical Balance*
*Set of Weights and Fractional Weights*
*Flat Aluminum Dish.*—Not less than 5 cm. in diameter, preferably with lid
*Tongs for Handling Dishes*
5-*c.c. Pipette*
*Desiccator*
*Farrington Oven with Thermometer*
100-*c.c. Volumetric Flask*
*Spatula*

**Procedure.**—An aluminum dish is heated for one-half hour in the oven at 212° F., cooled in the desiccator, and tared. It should be handled only with tongs. Five grams of the prepared sample (corresponding to 2 grams of the original sweetened condensed) are weighed into the dish. The test is completed as for milk, by the Farrington High-pressure Oven Method. When calculating results, the operator should be careful to use the weight of the original sweetened condensed milk as the "weight of the sample," instead of the weight of the prepared sample.

*Milk Powder*

**Preparation of Sample.**—The sample is taken and prepared as directed on page 282.

**Apparatus:**

*Butter Moisture Scales or Analytical Balance*
*Set of Weights and Fractional Weights*
*Flat Aluminum Dish.*—Not less than 5 cm. in diameter, preferably with lid
*Tongs for Handling Dishes*
*Desiccator Oven with Thermometer*
*Spatula*

**Procedure.**—The same procedure as directed for milk on page 292 is followed. A 2-gram sample is used, which must be weighed on an analytical balance. If butter moisture scales are used, a 10-grams sample will give more accurate results.

If the powder is very moist, it will crust over on the surface and prevent thorough drying. In such cases, it is better to prepare a 10 per cent solution by weight and test as for fresh milk by Farrington High-pressure Oven Method.

*Ice Cream*

**Preparation of Sample.**—The sample is taken and prepared as directed on page 283.

**Apparatus:**

*Butter Moisture Scales or Analytical Balance*
*Set of Weights and Fractional Weights*
*Flat Aluminum Dish.*—Not less than 5 cm. in diameter, preferably with lid
*Tongs for Handling Dishes*
5-*c.c. Pipette*
*Desiccator*
*Farrington Oven with Thermometer*

**Procedure.**—A clean aluminum dish is heated in the oven at 212° F. for one-half hour, cooled in the desiccator, and tared. It should be handled with tongs only. About 1 gram of the prepared sample is accurately weighed into the dish and about 4 c.c. of water (temperature 120° F.) are added and thoroughly mixed by a gentle rotary motion. A stirring rod cannot be used, as some of the sample may adhere to it. The test is completed as for milk by the Farrington High-pressure Oven Method.

**Hydrometer Method.**—The total-solids content of milk, condensed skim milk, and sweetened condensed skim milk, has been found to bear a fairly definite relation to the specific gravity and fat content. Since the fat content can be rapidly determined by the Babcock Method, a rapid method for determining the specific gravity is desirable. Hydrometers have been largely adopted for determining the specific gravity of these products.

The use of these hydrometers is based on the principle that, when a solid body floats in a liquid, it displaces an amount of liquid equal in weight to itself. Thus, it sinks deeper in a light liquid than in a heavy one, because it takes a larger volume of the light liquid to equal the weight of the floating body. Since the termperature of the liquid has a

very great effect upon its specific gravity, a hydrometer is correct only for the temperature used in standardizing it. In approximate work, however, a correction can be made for slight changes in temperature. The hydrometers used in determining the specific gravity of milk and its products are constructed[17] to be read to the top of the meniscus instead of at the level of the surface of the liquid. This change has been made because the opaque color of the meniscus renders it impossible to read the hydrometer accurately at the surface of the liquid.

### *Milk and Skim Milk*

A special form of hydrometer, called lactometer, has been devised for use in determining the specific gravity of milk. There are two types: the Quevenne, and the New York Board of Health, the main difference being in the scale. The Board of Health lactometer carries a scale graduated from 10 to 120 degrees, each division representing 2 degrees. The 100-degree mark corresponds to a specific gravity of 1.029, or a Quevenne reading of 29. The Quevenne lactometer is graduated from 15 to 40 in degrees. Each degree represents the third decimal of the specific gravity, thus making the calculation of the specific gravity rapid and easy. The Quevenne lactometer is more commonly used, because it is easier to estimate tenths of a degree in calculating the results into specific gravity and total solids, and because it generally carries a thermometer in it. All lactometer and thermometer scales should be tested for accuracy at least once a year, if they are used frequently. It will be found that the lactometer scales slide up or down in the spindle, thereby giving incorrect readings. The thermometer should be compared with one of known accuracy, one being placed close beside the other in the solution for at least a minute. The lactometer scale may be tested for accuracy by obtaining, as directed for milk on page 296, the lactometer reading of the following three solutions:

(1) A 3 per cent salt solution made by dissolving 12 grams of chemically pure sodium chloride in distilled water and diluting to exactly 400 c.c. This should have a specific gravity of 1.0217 and should give a Quevenne lactometer reading of 22 at 60° F.

(2) A 4 per cent salt solution made by dissolving 16 grams of chemically pure sodium chloride in distilled water and diluting to exactly 400 c.c. This should have a specific gravity of 1.029 and should give a Quevenne lactometer reading of 29 at 60° F.

(3) A 5 per cent salt solution made by dissolving 20 grams of chemically pure sodium chloride in distilled water and diluting to

[17] Unpublished data from the U. S. Bureau of Standards and manufacturers of lactometers.

exactly 400 c.c. This should have a specific gravity of 1.036 and should give a Quevenne lactometer reading of 36 at 60° F.

NOTE.—A volume of 400 c.c. is necessary adequately to float a lactometer in the cylinder. A good grade of butter salt, thoroughly dried, may be used in place of the sodium chloride for very rough work.

**Preparation of Sample.**—For lactometer determinations at least 1 pt. of milk is necessary. This milk should not be tested for at least two hours after being drawn from the cow. The sample should be taken and prepared as directed on page 269 except that no preservative should be added. The sample should be heated to 60° F. for accurate work, but corrections can be applied to the readings, provided the temperature is between 50° F. and 70° F.

**Apparatus:**

*Lactometer*

*Hydrometer Jar.*—A cylinder having a minimum height of 10 inches and a minimum diameter of $1\frac{1}{2}$ inches should be used.

**Procedure.**—The milk is mixed thoroughly by pouring from one container to another at least four or five times. The hydrometer jar is filled so that the addition of the lactometer will cause it to overflow slightly. This facilitates reading. The lactometer should remain in the milk one-half to one minute before being read. This allows the foam in the milk to escape and the thermometer to register correctly. If more than one minute is allowed, the butterfat may rise appreciably. The lactometer, which should not touch the sides or bottom of the hydrometer jar, is read to the top of the meniscus, being accurately estimated to a tenth of a degree. The temperature of the milk is recorded at the time of reading the lactometer. If it is not exactly 60° F., the lactometer reading must be corrected, for it is made to be accurate only at 60° F. The following correction may be applied if the temperature is not below 50° F. nor above 70° F. To correct a New York Board of Health lactometer, 0.3 of a lactometer degree is added to the observed reading for every 1° F. in temperature above 60° F. *Example:* Lactometer reading is 99.1 at 66° F. The corrected reading is $99.1 + (6 \times .3) = 100.9$ at 60° F. To correct a Quevenne lactometer reading, add 0.1 of a lactometer degree to the observed reading for every 1° F. in temperature above 60° F. Likewise subtract 0.1 of a lactometer degree for every 1° F. below 60° F. *Example:* Lactometer reading is 32.4 at 56° F. Correct reading is $32.4 - (.1 \times 4) = 32.0$ at 60° F.

Before any of the formulæ to calculate the specific gravity, total solids, or solids-not-fat may be applied, the lactometer reading must

be corrected for temperature. All New York Board of Health lactometer readings must also be changed to Quevenne readings.

To change a New York Board of Health reading to its equivalent in Quevenne degrees, the *corrected* New York Board of Health reading is multiplied by 0.29. This will give its equivalent, as a corrected Quevenne reading, which may be used in the following formulæ.

To calculate the specific gravity from the corrected Quevenne reading, 1000 is added to the corrected Quevenne reading and the total is divided by 1000. *Example:* Corrected Quevenne lactometer reading is 32.

$$\text{Sp. gr.} = \frac{32 + 1000}{1000} = 1.032$$

To calculate the total solids of the milk it is necessary to know the Babcock fat test as well as the corrected Quevenne lactometer reading. These values are substituted in the following formulæ:

$$\frac{\text{Corrected Quevenne lactometer reading}}{4} + (1.2 \times \text{Babcock fat test}) = \text{per cent total solids.}$$

*Example:* Assume that the sample of milk tested 3.8 per cent fat and gave a Quevenne lactometer reading of 32.0 degrees at 62° F.

The corrected Quevenne reading is found: $32 + (.1 \times 2) = 32.2$.

The total solids would be: $\frac{32.2}{4} + (1.2 \times 3.8) = 12.61$ per cent total solids. Or, $8.05 + 4.56 = 12.61$ per cent total solids.

*Plain Condensed and Sweetened Condensed Skim Milk*

**Preparation of Sample.**—The sample (at least 1 pt.) is taken and prepared as directed on pages 280, 281.

**Apparatus:**

*Baumé Hydrometer.*—A special Baumé hydrometer with scale graduated 12 to 26 (for plain condensed skim) or 26 to 37 (for sweetened condensed skim) in tenths of degrees.

*Hydrometer.*—A cylinder having a minimum height of 10 inches and a minimum diameter of $1\frac{1}{2}$ inches.

**Procedure.**—The sample is thoroughly mixed by pouring from one container to another at least four or five times. The hydrometer jar is filled so that the addition of the hydrometer will cause it to overflow slightly. This facilitates reading the hydrometer. The hydrometer is

carefully placed in the sample so that it does not touch the sides or bottom of the jar and is allowed to remain one-half to one minute. The hydrometer is carefully read to the nearest tenth of a degree, and the temperature of the sample recorded at the time of reading. By means of the following tables, the percentage of total solids in the sample is found. It must be remembered that these results are only approximately accurate, probably within 1 per cent.

TABLE LXXVI

BAUMÉ READING FOR SWEETENED CONDENSED SKIM MILK

| Temperature ° F. | Per Cent Total Solids | | | | | | |
|---|---|---|---|---|---|---|---|
| | 60 per cent | 63 per cent | 65 per cent | 68 per cent | 70 per cent | 73 per cent | 75 per cent |
| 100 | 31.1 | 32.7 | 33.8 | 35.4 | 36.3 | 37.8 | 38.9 |
| 105 | 31.0 | 32.6 | 33.6 | 35.3 | 36.1 | 37.6 | 38.6 |
| 110 | 30.9 | 32.5 | 33.5 | 35.1 | 36.0 | 37.5 | 38.5 |
| 115 | 30.8 | 32.3 | 33.3 | 35.0 | 35.8 | 37.3 | 38.3 |
| 120 | 30.7 | 32.2 | 33.2 | 34.9 | 35.7 | 37.2 | 38.2 |
| 125 | 30.6 | 32.1 | 33.0 | 34.7 | 35.5 | 37.0 | 38.0 |
| 130 | 30.4 | 31.9 | 32.9 | 34.6 | 35.4 | 36.9 | 37.9 |
| 135 | 30.2 | 31.7 | 32.7 | 34.4 | 35.2 | 36.7 | 37.7 |
| 140 | 30.0 | 31.6 | 32.6 | 34.3 | 35.1 | 36.6 | 37.6 |

TABLE LXXVII

BAUMÉ READING FOR PLAIN CONDENSED SKIM MILK

| Temperature ° F. | Per Cent Total Solids | | | | | |
|---|---|---|---|---|---|---|
| | 28 per cent | 30 per cent | 33 per cent | 35 per cent | 38 per cent | 40 per cent |
| 100 | 14.4 | 15.2 | 16.6 | 17.5 | 19.2 | 20.3 |
| 105 | 14.3 | 15.1 | 16.4 | 17.3 | 19.0 | 20.2 |
| 110 | 14.1 | 14.9 | 16.2 | 17.1 | 18.8 | 20.0 |
| 115 | 14.0 | 14.8 | 16.1 | 17.0 | 18.7 | 19.8 |
| 120 | 13.8 | 14.6 | 15.9 | 16.8 | 18.5 | 19.6 |
| 125 | 13.6 | 14.4 | 15.7 | 16.6 | 18.3 | 19.4 |
| 130 | 13.4 | 14.2 | 15.5 | 16.4 | 18.1 | 19.2 |
| 135 | 13.3 | 14.1 | 15.4 | 16.2 | 17.9 | 19.0 |
| 140 | 13.1 | 13.9 | 15.2 | 16.0 | 17.7 | 18.8 |

## METHODS OF ANALYSIS FOR ACIDITY

Milk when freshly drawn from the cow has the ability to react both acid and alkaline; that is, it can absorb a small amount of either an acid or a base without changing its acidity, because of certain acid salts which it contains. For this reason, milk is said to be amphoteric. The amount of acid found in freshly drawn milk is called the apparent or initial acidity and usually amounts to 0.10–0.14 per cent. After standing, milk increases in acidity on account of the growth of certain bacteria which change lactose, milk sugar, into lactic acid. The rapidity of this change depends upon the growth of those bacteria and this growth is more rapid at temperatures above 60° F.

When milk is received at the factory or is delivered to the consumer, it usually has an acidity (initial acidity plus the acidity due to the growth of bacteria) of from 0.15 to 0.20 per cent, 0.17 per cent being usually given as the acidity of fresh milk. Milk usually begins to taste sour when the total acidity has been increased about 0.1 per cent, that is, when the total acidity is from 0.25 to 0.30 per cent. While the maximum acidity that can be developed depends upon the amount of lactose and the type of bacterium present, milk seldom tests more than 1.20 per cent acid because most acid-forming bacteria cannot grow in a medium higher than that.

It is a well-known chemical phenomenon that 1 c.c. of N/10 alkali will exactly neutralize 1 c.c. of N/10 acid. Since 1 c.c. of N/10 lactic acid carries 0.009 gram of pure lactic acid, the number of cubic centimeters of N/10 alkali used, multiplied by 0.009, will give the total grams of lactic acid neutralized. This may be expressed as the formula

$$\frac{\text{c.c. N/10 alk.} \times 0.009}{\text{gram of sample}} \times 100 = \text{per cent acid.}$$

which is sometimes written

$$\frac{\text{c.c. N/10 alk.} \times 0.009}{\text{c.c. of sample}} \times 100 = \text{per cent acid.}$$

The second formula is sometimes more convenient to use but is not quite as accurate because 1 c.c. of the sample does not always weigh exactly 1 gram.

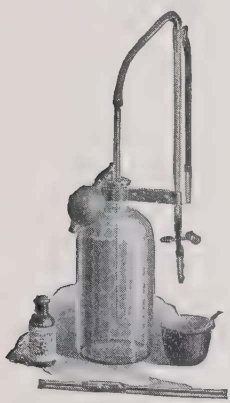
In order to tell exactly when the acid has been neutralized, a few drops of a chemical, called an indicator, are added. Indicators have the ability to change color with a definite change of acidity. For example, phenolphthalein is colorless in an acid or neutral solution but turns pink in an alkali. Therefore, if phenolphthalein is put into an acid and

alkali is added until a pink color is obtained, the solution has been changed to a base and all the acid neutralized. The first permanent appearance of the pink color indicates that the solution is changing from neutral to alkaline and this is taken as the "end-point" or stopping place. While phenolphthalein does not change color at the true neutral point, it is used in making acid tests on dairy products because its color change is most easily detected and comes very close to the true neutral point.

In making acid determinations, care should be taken to use a dilute solution of alkali, a small quantity of indicator, and the same shade of color for an "end-point." The strength and amount of alkali, as well as the amount of sample used, should be known exactly.

**Mann's Acid Test.**—This method depends upon the use of N/10 sodium hydroxide to neutralize the lactic acid, and phenolphthalein to indicate the neutral point. Sodium hydroxide is used as the alkali because it is cheap and easy to obtain.

This method shows the total acidity and is accurate to 0.01 per cent when carefully operated. Greater accuracy can be secured by weighing the samples or using larger ones. It does not show the true acidity, however, because of the fact that phenolphthalein remains colorless in very slightly alkaline solutions.



*Courtesy Creamery Package Mfg. Co.*

FIG. 74.—Apparatus for Mann's Acid Test.

*Milk*

**Preparation of Sample.**—The sample should be taken and prepared as directed on page 269, except that no preservative should be added.

**Reagents.**—The reagents for testing milk are as follows: N/10 sodium hydroxide (alkali) solution, which is made by dissolving exactly 4 grams of chemically pure sodium hydroxide sticks and making up to a liter with distilled water (it should be kept stoppered all the time because it becomes weakened if exposed to the air); phenolphthalein (indicator), which is made by dissolving 10 grams of chemically pure phenolphthalein powder in 300 c.c. of 90 per cent ethyl alcohol. Both of these solutions may be obtained from a dairy supply house, already prepared.

**Apparatus:**

*White Porcelain Cup*

17.6 *c.c. Pipette.*—The same as that used in the Babcock Method of testing milk for fat

*9-c.c. Pipette*

*50-c.c. Burette for measuring the Alkali used.*—An automatic burette which attaches directly to the alkali bottle may be obtained

*Burette Clamp and Stand*

**Procedure.**—17.6 c.c. of the prepared sample of milk are measured into the white cup, and 3 or 4 drops of phenolphthalein indicator added. From the burette, the N/10 alkali solution is slowly added, the mixture in the cup being constantly stirred until it turns to a faint pink color. This is the "end-point." The number of cubic centimeters of alkali used is recorded and divided by 20 to get the percentage of acid.

This method gives very accurate results, because the 17.6-c.c. pipette delivers practically 18 grams of milk. The formula therefore becomes

$$\frac{\text{c.c. N/10 alkali} \times .009}{18} \times 100 = \text{per cent acid},$$

or

$$\frac{\text{c.c. alkali}}{20} = \text{per cent acid.}$$

This relation exists only when the 17.6-c.c. pipette is used.

*Cream*

**Preparation of Sample.**—The sample should be taken and prepared as directed on page 273, except that no preservative should be added.

**Reagent and Apparatus.**—The reagent and apparatus are the same as those described under milk.

**Procedure.**—With a wide-mouthed 9-c.c. pipette, 9 c.c. of cream are measured into the white cup. The pipette is rinsed once with warm distilled water and the rinsing added to the cup to insure getting the entire 9 c.c. of cream into the cup. Three or four drops of phenolphthalein indicator are added and, while constantly stirring, N/10 alkali solution from the burette is added until a permanent faint pink color is obtained. The number of cubic centimeters of alkali used is divided by 10, or the formula on page 299 is used to get the percentage of acidity of the cream.

*Evaporated Milk, Sweetened Condensed Milk, Ice Cream, and Butter*[18]

These products not only contain large amounts of solids but also vary widely in specific gravity and therefore cannot be pipetted with

[18] This method gives the acidity due to the buttermilk in the butter instead of the total acidity which is due to the buttermilk and the fatty acids.

any degree of accuracy. Great care, as outlined on pages 280, 281, 283, and 287, should be used in preparing samples of these products. The same apparatus and reagents used in milk are also used in this test. Exactly 9 grams are weighed into the white cup and 9 c.c. of water and 3 or 4 drops of phenolphthalein added. (For butter the water should be 120° F.) Then, while constantly stirring, N/10 sodium hydroxide is added from a burette until a permanent faint pink color is obtained. The number of cubic centimeters of alkali used is divided by 10, or the formula on page 299 is used to obtain the percentage acidity.

*Ices and Fruit Juices*

The acid found in ices is largely citric. Consequently, it is necessary to modify slightly Mann's Acid Test in order to obtain the correct titratable acidity of ices. Citric acid, $C_6H_8O_7$, has a molecular weight of 192 and is trivalent. Thus, 1 c.c. N/10 alkali is equivalent to 0.0064 gram of pure citric acid. This factor is substituted in the formula on page 299 and gives $\frac{\text{c.c. alk.} \times .0064}{\text{grams of sample}} \times 100 =$ per cent acidity as citric acid.

Ices usually contain coloring matter, which interferes with obtaining a sharp, definite color change or end-point. To minimize this difficulty, the sample should be diluted with neutral water to at least four volumes.

**Preparation of Sample.**—The ice should be thoroughly melted, mixed and strained through cheese cloth to remove all fruit pulp, to prevent clogging of the pipette. Air bubbles should be allowed to escape. Care should be taken to prevent dilution and evaporation of sample.

**Reagents.**—The reagents for testing ice are the same as those given for milk, page 300.

**Apparatus:**

6.4 *ml.* (*c.c.*) *Pipette*—otherwise as for milk.

**Procedure.**—6.4 c.c. of the prepared sample should be accurately pipetted into the white porcelain cup. About 20 c.c. distilled water and 5 or 6 drops of phenolphthalein should be added. N/10 sodium hydroxide should be carefully poured from a burette until a permanent color change is obtained. This end-point may be a little difficult to obtain on account of the coloring in the ice; a "color change" instead of a definite shade of pink, therefore, should be taken as the end-point. The cubic centimeters of N/10 sodium hydroxide should be recorded and the percentage of citric acid calculated with the aid of the above formula.

Since the end-point is somewhat difficult to obtain, different operators may not agree within 0.02 or 0.03 per cent on the acidity of a given ice. An operator, however, should have no difficulty in duplicating his own results.

## ANALYSIS FOR SALT

Inasmuch as salt is an undesirable constituent of ice cream, it may be necessary to make a salt test on the butter used in the manufacture of the ice cream. This salt test may be easily made on the residue obtained from the determination of the butterfat.

This method is based upon the use of a fat-free sample and the following well-known chemical reactions:

$$(a)\quad AgNo_3 + NaCl \rightleftarrows AgCl + NaNO_3,$$

where the silver nitrate combines with the sodium chloride (salt) to form silver chloride, which settles out as a white precipitate. This takes place in the presence of large numbers of chlorine ions, but as the chlorine is reduced to silver chloride, the silver nitrate combines with the indicator ($K_2CrO_4$), thus:

$$(b)\quad 2AgNO_3 + K_2CrO_4 \rightleftarrows Ag_2CrO_4 + 2KNO_3;$$

but in the presence of any chlorine ions the silver chromate combines with the sodium chloride, thus:

$$(c)\quad Ag_2CrO_4 + 2NaCl \rightleftarrows 2AgCl + Na_2CrO_4.$$

When all the chlorine is used up, the silver nitrate combines with the indicator, $K_2CrO_4$, to give silver chromate, settling out as a brick-red precipitate, thus:

$$(d)\quad 2AgNO_3 + K_2CrO_4 \rightleftarrows Ag_2CrO_4 + 2KNO_3$$

Therefore, the first permanent appearance of the brick-red color is taken as the end-point of the titration.

**Reagents.**—The reagents are silver nitrate, in a solution which is made by dissolving 14.53 grams of chemically pure silver nitrate crystals in distilled water and diluting it to exactly 1 liter (it must be kept in an amber-colored bottle, as light causes it to turn dark); and potassium chromate solution, which is used for an indicator (it is made by dissolving 1 oz. of potassium chromate crystals in 100 c.c. of hot distilled water).

**Apparatus:**

*250-c.c. Volumetric Flask*
*25-c.c. Pipette*
*White Porcelain Cup*
*Stirring Rod*
*50-c.c. Burette,* graduated to tenths of a cubic centimeter
*Burette Clamp and Stand.*—An automatic burette attached to the silver nitrate bottle may be found more convenient

**Procedure.**—By repeated washings with hot distilled water (110° F. 43° C.), all of the residue from the aluminum cup (obtained in the Kohman Method of analyzing butter for fat) is washed into a 250-c.c. volumetric flask. The flask is filled exactly to the mark and its contents thoroughly mixed to insure complete solution of the salt. With a 25-c.c. pipette, 25 c.c. of the salt solution are drawn off and placed in the white porcelain cup. Three or four drops of potassium chromate solution are added; the burette is filled, and the silver nitrate solution added slowly, while constantly stirring, until the first permanent traces of a brick-red color are obtained. The color is considered permanent when it remains unchanged for a minute. The percentage of salt is calculated by dividing by 2 the number of milliliters (c.c.) of silver nitrate solution used.

The accuracy of this method depends upon (1) diluting the salt solution to exactly 250 c.c.; (2) using exactly 25 ml. (c.c.) of salt solution for titration; (3) having the correct strength of silver nitrate solution; (4) using the same end-point.

## ANALYSIS FOR GEL STRENGTH

Though there are many methods of testing the gel strength of gelatin, each having desirable features, a comparison is more important for practical purposes than an exact determination. The Invert Method is suggested, therefore, for use by the ice cream manufacturer.

**The Invert Method.**—This method is based on the fact that when solutions of gelatin are cooled, they tend to form gels which will not break or fall if inverted. The results are merely comparative but will agree very closely with depression methods.

**Reagents.**—The reagents for testing gelatin are distilled water; dilute hydrochloric acid, preferably N/10 solution; and dilute sodium hydroxide, preferably N/10 solution.

**Apparatus:**

*Glass Beaker,* exactly 2½ inches diameter and approximately 250 c.c. capacity

*Sterilizer*
*Spatula*
*Analytical Balance* (butter moisture scale)
*Set of Weights*
*Water Bath*
*Thermometer.*—The stem and bulb of the thermometer should be small
*Three* 100-*c.c. Burettes with Stands*
*Test Tubes*, $\frac{3}{4}$ by 8 inch, of clear glass and thin wall
*Brom-Thymol-Blue Indicator.*—It is best to purchase this solution already prepared, from a laboratory supply company
*Set of Brom-Thymol-Blue Color Standards.*—It is best to purchase these color standards, already prepared, from a laboratory supply company

**Procedure.**—Exactly 1 gram of gelatin is weighed into a test tube. This may be weighed on a piece of glazed paper and transferred to the tube, provided none is lost in the transfer. The test tube is filled about one-third full of distilled water and set in a water bath (temperature 145° F.) until the gelatin is dissolved. This usually takes fifteen minutes. Cold distilled water is added to fill the test tube about half full, and it is shaken thoroughly. Ten drops of Bromo-Thymol-Blue indicator are added and thoroughly mixed.

The color of this solution is compared with the set of color standards by placing the two tubes side by side against a white background. If the gelatin solution is yellower than the color standard for a *p*H of 6.6, it is necessary to adjust the *p*H by adding N/10 sodium hydroxide. The N/10 sodium hydroxide must be added from a burette and the exact amount used must be carefully recorded to a tenth of a cubic centimeter. The sodium hydroxide should be added in small quantities, a drop at a time toward the end, and mixed after each addition until the color of the gelatin solution is exactly the same shade as the color standard for *p*H 6.6. This result tells just how much N/10 sodium hydroxide is needed to adjust 1 gram of that particular gelatin to a *p*H of 6.6. If the gelatin solution is blue instead of yellow, N/10 hydrochloric acid should be used in place of N/10 sodium hydroxide and the same method followed.

Exactly 1 gram of the gelatin is weighed into a 250-c.c. beaker which has been thoroughly cleaned and sterilized. The exact amount of N/10 sodium hydroxide (or N/10 hydrochloric acid as the case may be) which has been found necessary to adjust the gram of gelatin to *p*H 6.6 is then added. Enough cold distilled water is added from a burette to make

exactly 100 c.c. of liquid (sodium hydroxide plus water), which is added to the gelatin and allowed to stand at room temperature for fifteen or twenty minutes. It is then set in a cold water bath and the temperature gradually raised until the gelatin solution is 145° F. (63° C.). The gelatin solution should be stirred frequently with the small thermometer while being heated. The water bath should be removed from the heat as soon as the gelatin reaches a temperature of 145° F. The gelatin is allowed to remain in the bath for exactly five minutes after reaching 145° F. It is then removed from the bath and thoroughly stirred with the thermometer. It should be placed immediately in a cold room (40° F.) free from dust and dirt, where it must remain undisturbed at 40° F. (5° C.) until thoroughly cooled, or for at least four hours. A sample should not be removed from the cold room or be disturbed until the reading is to be taken. The latter is made by placing one hand tightly over the top of the beaker while quickly and gently inverting it. A good gelatin will not break or fall out of the beaker, and the firmer the gel the better it is.

Since this method is purely comparative, it is necessary to run two samples simultaneously, treating them exactly alike. The results are always stated in the following manner: "Sample No. 1 has greater gel strength than sample No. 2."

The following steps are very important to the success of this test:

(1) The beakers must be uniform and exactly $2\frac{1}{2}$ inches in diameter.

(2) The beakers must be clean and sterile.

(3) The gelatin solution must be carefully and accurately adjusted to $p$H 6.6., as a slight change in $p$H will greatly affect the gel strength of the solution.

(4) The amount of liquid used to make the gelatin solution must be measured to exactly 100 c.c. in order to prevent any variation in concentration.

## ANALYSIS FOR GELATIN

The analysis of ice cream for gelatin offers many perplexing problems and, consequently, any method giving accurate results will be too long, tedious, and complicated for the ordinary laboratory operator to employ. Probably the most accurate method is described in detail by Ferris,[19] and, therefore, will not be repeated here.

[19] Ferris, L. W., A Method for the Quantitative Determination of Gelatin in Ice Cream. Journal of Dairy Science, Vol. 5, No. 6, p. 555, 1922.

## ANALYSIS OF MILK POWDER FOR SOLUBILITY

The term solubility is used to denote the ability of the powder, when mixed with water, to regain the physical and chemical properties of milk. For commercial conditions, the sediment method is sufficient, while for more accurate determinations the gravimetric test should be made.

### *Sediment Method*

This is based on the principle that a cotton disk will catch all the so-called insoluble powder from a definite amount of a 10 per cent solution (by weight), when filtered. The results are approximate or comparative because the amount of insoluble powder can only be estimated. The method has the advantage of being rapid and simple and of indicating the color of the insoluble material.

**Preparation of Sample.**—The powder is thoroughly mixed with a spatula. All lumps, however small, are carefully pulverized. This can best be done by mashing with a spatula on a glass plate.

**Apparatus:**

*Sediment Tester,* with cotton disk
*Butter Moisture Scales* (analytical balance)
*Set of Weights*
200-*c.c. Volumetric Flask*
*Beaker,* with lip, and a capacity of 100 c.c.
*Spatula*

**Procedure.**—Exactly 20 grams of the prepared sample are dissolved in warm water (110° F.). A paste is made and is then diluted to exactly 200 c.c. The sediment tester is assembled, the fuzzy side of the disk being away from the screen. All of the 200 c.c. of milk-powder solution is passed through the disk. The cotton disk is carefully removed so as not to lose or disturb any of the sediment. The disk is placed on a sheet of paper, properly labeled with sample number and other identification data. It may be examined immediately or after it has dried.

### *Gravimetric Method*

This methods consumes more time and is more difficult to use, but gives greater accuracy and allows the results to be expressed in a definite percentage.

**Apparatus:**

*Analytical Balance* (or butter moisture scales)
*Set of Weights*

*Spatula*
*Beaker*
200-*c.c. Volumetric Flask*
*Filter Paper*
*Glass Funnel*, 3 inches in diameter
*Equipment for Total Solids*

**Procedure.**—A 10 per cent solution of powder is prepared by weighing exactly 20 grams of the prepared sample into the beaker. A paste is made with warm water and thinned with more water. This should be transferred to the volumetric flask, all the milk powder solution being rinsed into the flask. The solution should measure exactly 200 ml. (c.c.). After it is filtered, a total-solids determination is made on the filtrate, and the total amount of powder in the filtrate calculated. The total weight of this calculation is divided by the weight of the powder to make up the solution, and the quotient is the percentage of solubility.

## ANALYSIS FOR FREEZING POINT

The determination of the freezing point is based upon the fact that, when any liquid freezes, the formation of ice crystals causes a certain amount of latent heat, called the latent heat of fusion, to be given off, and the giving off of this heat is indicated by a very rapid though slight rise in temperature. After the ice crystals start to form, the temperature remains constant until nearly all the liquid is frozen. This temperature is called the freezing point. Two things are necessary for freezing: (1) supercooling, which means cooling below the freezing point; and (2) either slight agitation or a nucleus to start the formation of ice crystals. The freezing point is lowered by increasing the concentration of those substances which go into true solution. The same concentration of different substances may have different freezing points, however. It is important to remember that a slight change in concentration will produce a great change in freezing point. The most common use in the dairy industry of the freezing point is to detect adulteration of milk, where a minimum of 3 per cent adulteration with water can be detected. The Hortvet Cryoscope has been specially constructed for freezing-point determinations of milk; any liquid can be substituted, however, with only minor changes in the procedure. The Hortvet Cryoscope is purchased complete, except for a pressure and suction pump, with instructions for operating.[20] Since ethyl ether is used in the cooling bath, flames must not be allowed in the same room.

[20] See also article by J. Hortvet. Jour. Ind. and Eng. Chem., Vol. 13, No. 3, p. 198, March, 1921.

Certain important precautions should be observed in the use of this method:

1. The sample should be taken and prepared as directed for solids test.
2. The clean freezing test tube should be rinsed with the prepared sample immediately before the sample to be tested is measured into it.
3. No drops of moisture should be permitted to collect on the inside of the freezing test tube or other apparatus that comes in contact with the sample.
4. Enough of the sample should be used completely to submerge the bulb of the freezing-point thermometer.
5. The ether bath should always be at 400 c.c. volume at the beginning of a determination.
6. The ether bath should be maintained at a constant temperature of about 2.5° C. below the freezing point of the liquid being tested.
7. A current of dry air should be constantly flowing through the ether bath.
8. No sulphuric acid or moisture should be allowed to get into the ether.
9. The thermometer should always be read with a lens, care being taken to avoid parallax.

## ANALYSIS FOR BACTERIA

Bacterial analyses are reliable only when made by operators who have been carefully trained and who have had a certain amount of experience. Since bacteria are too small to be seen with the naked eye, it is very difficult to appreciate the error introduced by the oversight of a small detail.

### Agar Plate Method[21]

This method is the one most commonly used, for it readily lends itself to the analysis of all dairy products. It is based on the fact that, under favorable conditions of temperature, food, and moisture, one organism will grow and in time make a colony large enough to be seen with the naked eye. When a known quantity of the product to be analyzed is placed under these carefully controlled favorable conditions, the number of bacteria in that quantity can be counted with the naked eye. That each colony originates from a single organism is a supposition which may not be true, for the organisms frequently exist in clumps. The method has the important advantage, however, of counting only

[21] Taken in part from Standard Methods of Milk Analysis, 4th Edition, 1923. Published by the American Public Health Association.

the organisms that are alive and are capable of injuring the quality of the product. Since 1 c.c. of milk or 1 gram of butter may contain millions of bacteria, it is obviously impractical to try to count them all. Therefore, so-called "dilutions" are made in order to reduce the number of bacteria colonies which have to be counted. The sample is diluted by placing a known quantity in an accurately measured amount of sterile water, called a water blank, so that the sample bears to the final volume such a ratio as 1 to 10, 1 to 100, or 1 to 1000. For example, if 1 c.c. of milk is placed in 99 c.c. of sterile water, the dilution is 1 to 100. Ten cubic centimeters of milk in 90 c.c. of sterile water, or 1 c.c. of milk in 9 c.c. of sterile water gives a 1 to 10 dilution. Then if 1 c.c. of the 1 to 10 dilution is placed in 9 c.c. of sterile water it is diluted further and that is called a 1 to 100 dilution, this being the ratio of the original milk to the final dilution. Similarly, 1 c.c. of a 1 to 100 dilution placed in 99 c.c. of sterile water gives a 1 to 10,000 dilution. Other dilutions can be made in the same manner. The same pipette should not be used for more than one dilution, and each dilution should be thoroughly mixed as soon as the sample is pipetted into it.

**Samples.**—In all analytical work, the sample is the most important feature, because an inaccurate sample will unavoidably give inaccurate results. For bacterial analysis, it must be remembered that contact with any apparatus which is not absolutely sterile will contaminate the sample and make the results worthless. The fact that the apparatus has been sterilized is not enough; it must be protected from contamination until used. Too much care cannot be given to this matter. All samples should be placed in cracked ice as soon as taken, and kept at a temperature below 50° F. (10° C.) until analyzed.

Milk and cream and all liquid products should be sampled with a sterile sampling tube. After the cotton plugs are removed, the tube should be slowly inserted to the bottom of the container, thus removing a sector of the contents, which is put into a sterile sample bottle. The stopper should not be laid down, as contamination of the sample is likely to occur. At least 50–100 c.c. should be taken for each sample; and at least six (and preferably more) samples from as many different places in the vat as possible should be taken after the liquid has been thoroughly mixed. Liquids may also be sampled by catching some of the material in a sterile sample bottle at periodic intervals as it is being poured from one container to another.

Milk powder, gelatin, and sugar should be thoroughly mixed with a sterile spatula and a portion placed in a sterile sample bottle.

When butter or ice cream is being sampled, the surface inch should be removed by a sterile spatula from the point to be sampled. With

another sterile spatula, a core should be cut out and placed in a sterile sample bottle.

All glassware should be sterilized in the dry-air sterilizer at 170–180° C. for one to two hours. Pipettes and Petri dishes should be wrapped in paper or enclosed in metal containers to prevent contamination upon removal from the sterilizer. Cotton plugs should be inserted in each end of the sampling tubes, and one to four tubes should be completely wrapped in paper or metal containers before sterilization.

**Reagents.**—The reagents for bacteria tests are as follows: normal sodium hydroxide, which is made by dissolving 40 grams of chemically pure sodium hydroxide sticks in distilled water; N/10 sodium hydroxide, which is prepared by accurately diluting normal sodium hydroxide to ten times its volume; Brom-Thymol-Blue indicator (it is best to purchase this, already prepared, from a laboratory supply company); 99-c.c. water blanks and 9-c.c. water blanks (these are prepared by placing either 103 c.c.[23] of pure distilled water in a flask, or $9\frac{1}{2}$ c.c.[22] of pure distilled water in a test tube, fitting with a cotton plug, and sterilizing in the autoclave for thirty minutes at 15 lbs pressure); and standard agar, which is prepared by adding 0.3 per cent beef-extract (Difco), 0.5 per cent peptone (Difco), and 1.5 per cent market agar to the desired number of liters of distilled water. It is dissolved by heating in an autoclave for forty to ninety minutes after the pressure has reached 15 lbs., the length of time depending upon the quantity of media prepared. When completely dissolved, it is removed from the autoclave. One cubic centimeter of the agar is placed in a test tube with 4 c.c. of hot distilled water (85–100° F. and no warmer). Ten drops of Brom-Thymol-Blue are added and thoroughly mixed. Its color is tested by holding it beside the color standard tube at an angle of 45° against a white background. The *p*H of the color-standard tube that exactly matches the color of the agar tube is the *p*H concentration of the agar medium. This should be between *p*H 6.2 and *p*H 7.0; the most desirable reaction, however, is *p*H 6.6.

If necessary, the *p*H is adjusted by the following method: One cubic centimeter of agar is added to 4 c.c. of hot distilled water (85–100° F., not warmer) in a test tube. Ten drops of Brom-Thymol-Blue are added and thoroughly mixed. Tenth normal sodium hydroxide is added slowly from a burette and mixed frequently until the color exactly matches the color standard for *p*H 6.6. The amount of N/10 sodium hydroxide added from the burette, multiplied by 25, is the amount of normal sodium hydroxide to be added to one liter of the agar to adjust the *p*H to 6.6. After the *p*H is adjusted, the media should be filtered through

[22] The additional amount is due to loss during sterilization and cooling.

a cotton filter, placed in flasks of 100 c.c. each or in test tubes of 10 c.c. each, plugged with cotton, and sterilized in the autoclave at 15 lbs. pressure for twenty minutes. They are then removed from the autoclave and stored at a temperature of 40° F. until ready to use.

**Apparatus:**

*Set of Brom-Thymol-Blue Color Standards.*

50-*c.c. Burettes, graduated in tenths of a cubic centimeter,* one for normal sodium hydroxide; one for N/10 sodium hydroxide. (Automatic burettes attached to the bottle may be used, in which case the burette clamps and stands are unnecessary)

*Burette Clamps and Stand*

*Test Tubes, $\frac{3}{8}$ inch in Diameter.*—The glass should be very clear and should have a thin wall (for making *p*H determination)

*Flasks,* of 100-c.c. capacity, for water blanks

*Test Tubes, $\frac{5}{8}$ inch Diameter* (for 9-c.c. water blanks)

*Sampling Tubes,* which should be of $\frac{1}{2}$-inch glass or aluminum tubing 36 inches long.

1-*c.c. Pipettes.*—These should be straight-sided and graduated to deliver 1 c.c.

*Petri Dishes,* whose bottoms or smaller halves should have inside diameters of 10 cm.

*Absorbent Cotton,* for plugs in water blanks and media flasks

*Flasks,* of 2 liters capacity, for making up media

*Erlenmeyer Flasks,* with a capacity of 150 c.c., in which to sterilize the media

*Laboratory Balances* (butter moisture scales)

*Set of Weights and Fractional Weights*

*Spatula*

*Autoclave*

*Dry-air Sterilizer*

*Tally Meter*

*Wax Pencil,* for writing on glass

$3\frac{1}{2}\times$ *Hand Lens*

## Volumetric Method

This method is used for analyzing milk, cream, skim milk, and evaporated milk, which are not very viscous. To insure uniform results with very rich cream, it is better to use the gravimetric method, because the pipette does not deliver uniform quantities of heavy cream. The volumetric method is very rapid and less tedious than the gravimetric one, and gives results in bacteria per cubic centimeter. The sample

should be thoroughly mixed by shaking, before removing the quantity to be diluted. The larger the volume used in making the first dilution, the smaller the error in measuring the sample.

By means of a sterile pipette, the amount of the sample to be diluted (1 c.c. assumed) is accurately measured into a sterile water blank of the proper size (99 c.c. assumed) thus obtaining a 1 to 100 dilution. The pipette should never be laid down while being used. The tip of the pipette should be flamed (passed through a flame) before being inserted into the sample. The cotton plug of the sterile water blank should be removed and held in the fingers while the mouth of the water-blank bottle is flamed and the 1 c.c. of milk delivered into the sterile water. The plug is replaced and the milk thoroughly shaken with the sterile water. The pipette should then be laid down and not used again for bacteriological work until thoroughly washed and sterilized. With a clean, sterile pipette, 1 c.c. of this dilution is transferred to each of two clean, sterile Petri dishes. The cover of the Petri dish is raised only enough to permit the 1 c.c. of liquid to be delivered in the center of the plate. The tops of these plates should have been previously labeled, by means of a wax pencil, with the sample number, the dilution ratio (1 to 100), the date, and any other information desired. Before the pipette is put down, another 1 c.c. of the dilution is transferred to a new sterile 9-c.c. water blank with the same care and precaution as in making the first dilution. The dilution has now become 1 to 1000. The pipette should be discarded for washing. The second dilution is thoroughly mixed, and, with a clean, sterile 1-c.c. pipette, 1 c.c. is transferred to each of two clean, sterile Petri plates, which have been previously labeled. It is necessary to make duplicate plates on each dilution plated and to plate at least two dilutions. The most common dilutions on these products are 1 to 100 and 1 to 1000, or 1 to 1000 and 1 to 10,000; but higher ones may be found necessary.

After the diluted sample is placed in the Petri dishes, about 10 c.c. of agar are added. The sterile agar should be completely melted and then cooled to a temperature of 110° F., at which temperature it should be poured into the Petri plates. This temperature is easily determined, after a little practice, by placing the flask of agar on the arm. Great care must be used to have this temperature correct, because if the agar is too hot it will kill the organisms, and if too cold it will become lumpy, making a thorough mixing impossible. In pouring the agar into the plates, the plug is removed first, the mouth of the flask flamed, and the lid of the plate raised only enough to allow the agar to be poured into the middle of the plate and about 10 c.c. of agar introduced. The lid is closed and the agar thoroughly mixed with the 1 c.c. of diluted sample

by a gentle rotary motion. It is allowed to stand undisturbed in a level position until the agar has solidified.

The plates are then inverted and placed in an incubator at a temperature of 37° C. for exactly forty-eight hours. To secure good results, all plates should have equal incubation temperatures and should remain undisturbed during this period.

At the end of the incubation period, the colonies may be seen with the naked eye as white or sometimes colored spots in or on the agar. Each colony, whether large or small, should be counted, a spot of ink being used to mark it as it is counted with a tally meter. After all visible colonies are counted the plates should be further examined with a hand lens ($3\frac{1}{2}\times$) to detect any others. This final count should also be recorded. The counting should be completed as soon as possible after removing the samples from the incubator.

Only those plates containing from 30 to 300 colonies should be counted. Usually those containing around 100 are the most accurate. If duplicate plates do not check within 10 per cent of each other, more careful technique is required. The average count on the duplicate plates must be multiplied by the dilution marked on the top of the plates to give the bacterial analysis of the original sample. For example: if 200 and 190 were the respective number of colonies found on duplicates of a 1 to 1000 dilution, the milk would contain $195 \times 1000 = 195{,}000$, the number of bacteria per cubic centimeter.

The plates can then be thoroughly washed, dried, and sterilized.

## Gravimetric Method

This method is recommended for the analysis of gelatin, milk powder, sugar, butter, sweetened condensed milk, and ice cream or ice cream mix. These solid samples are sometimes reported on a volumetric basis, which refers to a plate count per cubic centimeter of a 10 per cent solution or suspension, by weight. The gravimetric method is based on the sample's being weighed instead of measured, and the results are reported in bacteria per gram, instead of per cubic centimeter as in the volumetric method.

Samples of gelatin, milk powder, and sugar should be thoroughly mixed and handled entirely by a sterile spatula. The same one may be used repeatedly if it is flamed before being placed in the sample. Butter samples should be cut into very fine pieces with a sterile spatula.

A pair of cornet forceps and a sterile water blank containing 90 c.c. are carefully counterbalanced on the moisture scales. A 10-gram weight is placed on the opposite scale pan, the plug removed from the water

blank and suspended over the edge of the pan by means of the forceps, care being taken that the plug does not touch anything. The mouth of the water blank is flamed, and exactly 10 grams of the sample to be analyzed are introduced. The mouth of the water blank is flamed and the plug replaced. This gives a 1 to 100 dilution. It may be more convenient to use a known weight of sample instead of exactly 10 grams, but in this case it would be necessary to calculate the dilution. To insure equal distribution of the sample, water blanks used in diluting gelatin or butter samples should be heated to 105–110° F. (41–43° C.) before the sample is introduced. Other dilutions are made and the plating continued as in the volumetric method. The most common dilutions for these products are the following: sugar, 1 to 10 and 1 to 100; gelatin, from 1 to 10, up to 1 to 100,000; all others, from 1 to 100, up to 1 to 10,000.

## Direct Count, or Breed Method

This method is based upon the use of a microscope to count the bacteria after they have been stained with a dye so that they are easily seen. It required the use of a solution; and unless the sample is already liquid, it is advisable to make a 10 per cent solution or suspension by weight. In this method, exactly 1/100 c.c. of liquid is evenly spread over exactly 1 sq. cm. of a clean glass slide and dried. The fat in the film is removed by xylol, and a solution of Loeffler's Methylene Blue is applied to stain the film, which is then decolorized with alcohol until the bacteria are easily seen. The film is examined under a microscope which has a field of exactly 0.205 mm. diameter. The number of bacteria in several fields are counted and the average multiplied by 300,000 to give the number in each cubic centimeter of the liquid examined.

The important disadvantages are (1) that a small error in the technique will produce a large error in the results and (2) that all organisms, both dead and alive, are counted. Obviously, for pasteurized products, such as milk powder, etc., this method is of little value, because the ice cream manufacturer is interested only in the number of live organisms present. Its principal advantage is the rapidity with which it may be used.

## CHAPTER XI

## ENGINEERING IN THE ICE CREAM PLANT

**Importance of Engineering Knowledge.**—The manufacture of ice cream entails the application of many laws of physics, especially in the process of pasteurization and freezing, which necessitates the use of considerable machinery. The well-equipped ice cream plant has a steam plant, pasteurizers, hotwells, coolers, freezers, electric motors, refrigeration machinery, and many other smaller types of equipment. The ice cream manufacturer, consequently, has many problems of an engineering nature. Since the operation of the machinery constitutes a large part of the production cost, every effort should be made to manage the equipment properly and keep it in perfect mechanical condition, thus raising its efficiency.

**Heat.**—Since the freezing of ice cream is a process in which heat plays a large part, consideration should be given to the principles underlying the measurement and utilization of heat. Heat is a source of energy. According to the theory generally accepted, heat is a resultant of, or is at least connected with, the motion of the molecules of a body, and its intensity, or the temperature, depends upon the velocity and amplitude of this motion.

Most bodies expand when heated. This expansion is probably due to the increased velocity of the molecules, which forces them farther apart and increases the actual size of the body. The vibration may become so violent that the attraction between the molecules is partly overcome and the body can no longer retain its form. In this case the solid becomes a liquid. If still more heat is added, the attraction of the molecules may be entirely overcome by their violent motion, and the liquid then becomes a gas.

**Temperature and Temperature Measurement.**—Unless otherwise stated, the temperatures given in this chapter will be taken on the Fahrenheit scale, that on which temperature is usually measured. The Centigrade scale is sometimes used. A comparison of the two scales is made in the following paragraphs.

The graduations on the Fahrenheit scale are obtained by noting the positions of the mercury column when the bulb of the thermometer is

placed in melting ice and when it is placed in boiling water under an atmospheric pressure corresponding to sea-level barometer. The distance between these two points is divided into 180 equal parts, or degrees. The freezing point is arbitrarily taken as 32° above zero of the scale, thus making the boiling point 32° plus 180° or 212° above zero.

On the Centrigrade scale, the distance between the freezing point and the boiling point is divided into 100 equal parts or degrees, and the freezing point on the scale is marked 0°. The boiling point is then 100°.

Since in the Fahrenheit scale there are 180 divisions between the freezing and boiling points and on the Centigrade 100 divisions, it fol-

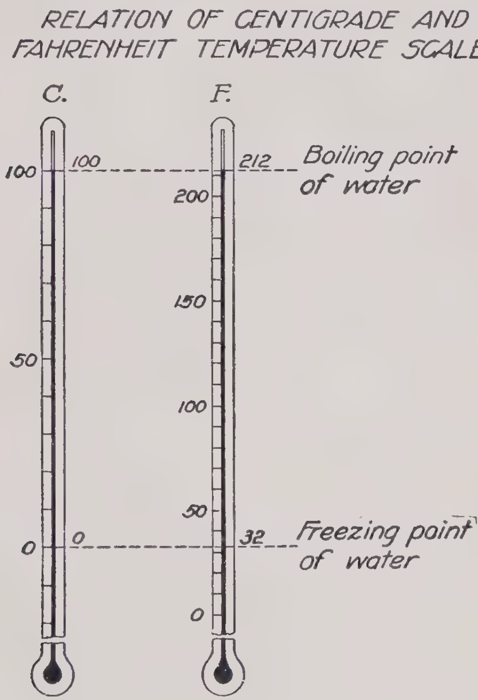



FIG. 75.

lows that 1° F. = $\frac{5}{9}$° C., or 1° C. = $\frac{9}{5}$° F. As, however, the freezing point on the Fahrenheit scale is marked 32 and on the Centigrade scale 0, it is necessary to take account of this difference when converting from one scale to the other. If the temperature Fahrenheit be denoted by $t_f$ and the temperature Centigrade by $t_c$, then the conversion from one scale to the other may be made by the following equations: See Fig. 75.

$$t_f = \tfrac{9}{5}t_c + 32; \qquad (1)$$

$$t_c = \tfrac{5}{9}(t_f - 32). \qquad (2)$$

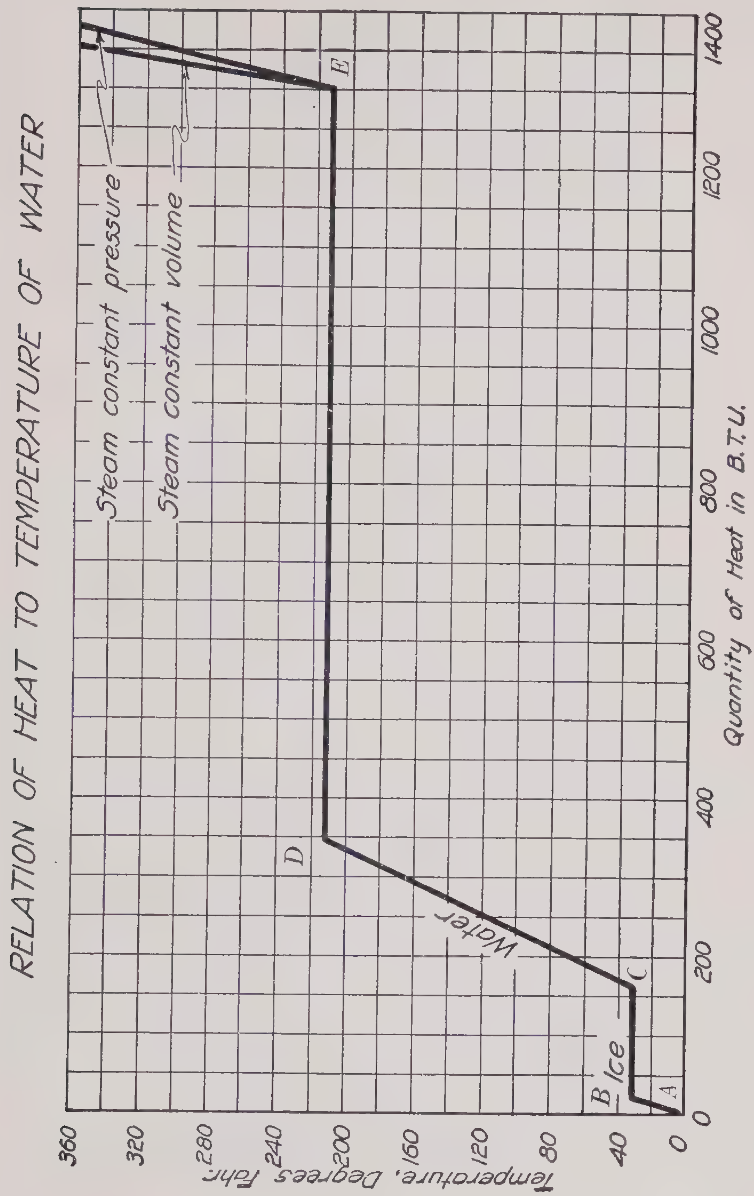
**The Unit of Heat.**—Heat is not a substance, and it cannot be measured as water would be, in pounds or cubic feet, but it must be measured by the effect which it produces. The unit of heat used in engineering is the heat required to raise a pound of water one degree Fahrenheit. The heat necessary to raise a pound of water one degree does not remain the same throughout any great range of temperature. For physical measurements where accuracy is required, it is necessary to specify at what point in the scale of temperatures this one degree is to be taken. Many authors specify that *the heat unit is the amount of heat required to raise a pound of water from* 39° *to* 40° *Fahrenheit.* The range from 39° F. to 40° F. is used because at this temperature water has its maximum density. This unit is called a *British Thermal Unit,* and is denoted by *B.T.U.* The heat unit used in Marks and Davis' tables is the "mean B.T.U.," that is, $\frac{1}{180}$ of the heat required to raise one pound of water from 32° to 212° at atmospheric pressure (14.7 lbs. per square inch absolute).

**Kinds of Heat.**—Heat is absorbed by a body in two different ways. These are sometimes known as the three types of heat. In the accompanying diagram, showing the relation of heat to temperature of water, these three types of heat are illustrated.

When a certain quantity of heat has been added to ice, point *A* on the curve, there occurs a rise in temperature, point *B*. This is an illustration of sensible heat. Sensible heat, therefore, may be defined as the addition of heat accompanied by a temperature rise of the body. Between points *B* and *C*, heat is added to the ice, but there is no change in temperature. The heat added during this time is called latent heat, for it has been absorbed in this particular instance in the changing of the ice to water and has not produced a temperature change. Latent heat may be defined as heat that is absorbed by a body and is not accompanied by a change in temperature. Between points *C* and *D*, more heat is added; a rise in temperature now takes place. This is another example of the addition of sensible heat. From *D* to *E* still more heat is added but with no temperature change; this is a further example of the addition of latent heat.

The great heating effect of steam is made possible by condensation, or the giving up of latent heat.

**Specific Heat.**—If the temperature of a body is raised or lowered a definite amount, a certain amount of heat must either be added to or given up by the body. The heat capacity of any substance compared with that of an equal weight of water is called its specific heat. If expressed in English units, the heat capacity of one pound of water is one B.T.U., and specific heat may be defined as the heat necessary to




Source: Bul. 98, U.S.D.A.

FIG. 76.

raise the temperature of one pound of a substance one degree Fahrenheit, expressed in British Thermal Units.

TABLE LXXX

Specific Heat Materials *

| Material | Specific Heat |
|---|---|
| Air | 0.2375 C.P. |
| Water | 1.00 |
| Alcohol | 0.54 to 0.769 (Temp. 32–176) |
| Milk | 0.93 |
| Sulphuric acid | 0.3363 |
| Aluminum | 0.218 |
| Cadmium | 0.056 |
| Copper | 0.093 |
| Iron | 0.110 |
| Lead | 0.031 |
| Mercury | 0.032 |
| Nickel | 0.108 |
| Platinum | 0.032 |
| Tin | 0.055 |
| Zinc | 0.094 |

* Adapted from Smithsonian Tables.

**Transfer of Heat.**—Heat may be transferred from one body to another. In the case of a heating plant or a pasteurizer, heat is carried from a warm object to a cooler one. This flow of heat follows a natural law, which says that two bodies of different temperature, if placed near to each other, will tend to become of the same temperature, the warmer object giving off heat to the cooler one. Heat may also be transferred from a colder object to a warmer one, but this is not a natural process and requires the use of a refrigeration machine. There are only three natural methods of heat transfer. The first is by radiation, which is similar to the way in which light is radiated from a lamp. There is always a transfer of radiant heat from a body of high temperature to one of low temperature. The amount of heat radiated depends upon the difference in the temperature between the bodies and upon the character of the substance.

A practical application of the information given in Table LXXXI is that of the effect of keeping radiating surfaces well polished, if it is desired to reduce the amount of heat radiated. Table LXXXI shows

that with polished copper the heat radiated per square foot per degree difference in temperature is 0.0327 B.T.U., while for rusted cast iron the radiating capacity is 0.648 B.T.U. or approximately 18 times as much. This explains why the rusty stove found in the old country grocery store was a much better heater than the modern highly polished radiator.

TABLE LXXXI *

RADIATING POWER OF BODIES

Radiating power of bodies, expressed in heat units, given off per square foot per hour for a difference of one degree Fahrenheit (Perclet)

| | B.T.U. |
|---|---|
| Copper, polished | 0.0327 |
| Iron, sheet | 0.0920 |
| Glass | 0.595 |
| Cast iron, rusted | 0.648 |
| Building stone, plaster, wood, brick | 0.7358 |
| Woolen stuffs, any color | 0.7522 |
| Water | 1.085 |

*Allen, J. R., and Bursley, J. A., Heat Engines, p. 7. McGraw-Hill Book Company, New York.

A second method by which heat is transferred is that of conduction through the body itself. The amount of heat conducted will depend upon the material of which the body is composed and the difference of temperature between the two sides of the body. It is also inversely proportional to the thickness of the body. Heat will be conducted from one body to another when the two are placed in contact with each other. Table LXXXII shows the conducting power of different bodies.

TABLE LXXXII *

CONDUCTING POWER OF BODIES

Approximate B.T.U. transferred per hour, per square foot per degree F. difference in temperature, per inch thickness

| | B.T.U. |
|---|---|
| Copper | 2900.0 |
| Iron | 438.0 |
| Nickel | 400.0 |
| Tin | 420.0 |
| Glass | 6.6 |
| Brickwork | 4.8 |
| Plaster | 3.8 |
| Pine wood | 0.75 |
| Air | 0.2087 |
| Water | 3.94 |

*Adapted from Smithsonian Tables.

**Transfer of Heat by Convection.**—When air or any other gas comes in contact with a hot body, it becomes warm and rises, carrying away heat from the hot body. Heat carried off in this manner is said to be lost by convection. This loss is independent of the nature of the surface—wood, stone, and iron losing the same amount—but it is affected by the form and position of the body.

**Transfer of Heat by Conduction.**—The amount of heat conducted through a wall of metal, wood, or any material may be calculated by the use of the following formula, provided that the proper values for constant $K$ can be found.

$$Q = \frac{K \times A(t_1 - t_2) \times T}{D}$$

$Q$ = B.T.U. transferred per second

$K$ = Conductivity constant for the material of the wall and represents the heat conducted through one square foot of the material one inch thickness per hour per degree F. difference in temperature of the two sides of the wall.

$A$ = The area of the heating surface in square inches

$t_1$ = Temperature of hot side of wall, (°F.)

$t_2$ = Temperature on colder side of the wall, (°F.)

$T$ = Time in seconds

$D$ = Thickness of wall in inches.

**Factors Reducing the Efficiency of Heat Transfer.**—Where heat is transferred from one body to another through a wall, for instance, in the heating of water, there is a tendency for a thin film of the water to be in contact with the wall and remain at approximately the same temperature as the wall. The conductivity of water is approximately $\frac{1}{581}$ that of copper and, therefore, this film of water will tend to reduce the rate of heat transfer. This film of hot water, then, must be constantly removed in order to obtain the best heat transfer. This can best be done by moving the water rapidly across the surface of the wall. This explains the necessity of agitation in a vat of milk, if the milk is to be heated quickly. The agitation constantly removes the film of liquid near the wall, preventing the formation of a heated film.

Inefficient heat transfer is also caused by burning the solids on the heating surface. The effect is somewhat the same as that of a layer of water, since the deposit acts as an insulator and prevents rapid heat transfer. The burning on of solids may be caused by carrying the temperature of the heated wall too high, by using a conducting surface which is too thin, or by failure to agitate the liquid that is being heated.

**Work, Energy, and Power.**—Work is the overcoming of resistance through space and is measured by the resistance in pounds, multiplied by the distance in feet through which the body is raised. The simplest form of work is that of raising a body against the force of gravity. If a weight of 10 lbs. is lifted 12 feet., the amount of work done is $12 \times 10 =$ 120 ft.-lbs. Similarly, if the rim of a flywheel is pulled with a force of 10 lbs. and the wheel is turned with the same pull until a point on the rim has traveled 12 feet, 120 ft.-lbs. of work will also be accomplished. Work is not dependent upon the time consumed.

Energy is the capacity for doing work. Gasoline, for example, has a heating value of 20,000 B.T.U. per pound, or approximately 120,000 B.T.U. per gallon. One B.T.U. of heat, if completely transformed into work, would produce 778 ft.-lbs. of work. Therefore, the total energy (or the capacity for doing work) which was contained in the gallon of gasoline would be 120,000 times 778, or 93,360,000 ft.-lbs. of work.

Power is the time rate of doing work. The common unit of power is the horse-power. One horse-power is equivalent to raising 33,000 lbs. one foot in one minute, or, as sometimes stated, is equivalent to the doing of 33,000 ft.-lbs. of work per minute. This is the unit employed in rating engines and motors. Power may also be expressed in electrical units. The kilowatt is the electrical unit of power; 1 kilowatt equals 1.34 horse-power.

**The Law of Conservation of Energy.**—Energy cannot be destroyed, but it may be transformed from one form to another. For instance, in the operation of a steam engine, a part of the heat goes into useful work, another part is exhausted from the engine, and another is lost by radiation from the hot surfaces. None of this energy is destroyed; it may all be collected again. If a given amount of heat is added to an object, it may all be accounted for.

## STEAM

Steam equipment is very largely used in ice cream plants, both for power and for processing. At the present day, however, a large percentage of the power used is obtained from electric motors. The concern here is more with the steam used in processing than with that used for power. Steam is produced by heating water. Referring to Fig. 76, it will be observed that for every pound of water which is changed into steam, approximately 1000 B.T.U. of heat must be added. This heat energy is then given up again when the steam is condensed. It can be readily seen that steam forms a very convenient medium for the transfer of heat, as it carries a very large amount of heat per pound.

**The Formation of Steam.**—Steam as produced in the ordinary boiler is a vapor. It often contains a certain amount of water in suspension, as does the atmosphere in foggy weather. If heat is applied to the external shell of a boiler partly filled with cold water, the water in the boiler is heated and its temperature slowly rises. This increase in temperature continues from the initial temperature of the water until the temperature of boiling water is reached. When the boiling point is reached, small particles of water are changed into steam. These rise through the mass of water and escape to the surface. The water is then said to boil. The temperature at which the water boils depends upon the pressure in the boiler. The water is at the same temperature as the steam; under this condition, the steam is said to be saturated. If heat is continually applied to the water in the boiler, the pressure remaining the same, the temperature of the steam and the water will remain constant until all the water is evaporated. If more heat is added after all the water is converted into steam, the pressure still being kept unchanged, the steam under this condition is said to be superheated. The heat absorbed in the formation of steam might then be divided into three parts, as mentioned under kinds of heat. First, there is the heat that is used up in raising the temperature of the water from its initial temperature to the temperature of the boiling point. This is called the heat of the liquid. Second, there is the heat that is used up in changing the water at the temperature of the boiling point into steam at the temperature of the boiling point. This is called latent heat. Third, there is the heat used up in changing the saturated steam at the temperature of the boiling point into steam at higher temperatures but at the same pressure. This is called heat of superheat.

The three different types of steam are as follows: first, dry saturated steam, which always exists at the temperature of the boiling point corresponding to the pressure and contains no moisture in the form of water; second, wet steam, which contains small droplets of water; third, superheated steam, which is steam at a temperature higher than that of the boiling point corresponding to the pressure. Superheated steam may have any temperature higher than the boiling point.

The exact amount of heat carried by the steam has been very accurately determined by the United States Bureau of Standards and may be readily ascertained from steam table, page 388. In this table are found columns which give the temperature of the steam, the heat of the liquid, the latent heat of vaporation, and the total heat of the steam for every corresponding pressure.

In working out the steam table, it was necessary to fix a starting point for the measurement of the temperature; this has arbitrarily been

set at 32° F. or, in other words, the freezing point of water. Therefore, in the use of the steam table, it should be noted that the heat of the liquid is the amount of heat, in B.T.U., contained in one pound of the water above what it had at 32° F. The latent heat of vaporization is the amount of heat, in B.T.U., necessary to change the water into steam at the given pressure; and the total heat of the steam, as shown in the table, represents the total number of B.T.U. of heat added to the pound of water above that it had at 32° F. It also represents the amount of heat which would be given up if the steam were condensed and cooled down to 32° F. The total heat of one pound of wet steam is given by the formula $h + ql =$ B.T.U., in which $h$ is the heat of the liquid, $q$ is the per cent or quality of the steam, and $l$ is the latent heat of vaporization at the given pressure. For instance, if it is necessary to determine the amount of heat given up by one pound of steam at 30 lbs. pressure, when the quality of the steam was 90 per cent, the following method of calculation should be used:

$$h = 218.9 \text{ B.T.U.}$$

$$l = 944.8 \text{ B.T.U. total heat across}$$

$$218.9 + .90 \times 944.8 = 1069.3 \text{ B.T.U.}$$

If this steam had been dry, it would have contained 1163.7 B.T.U. Using dry steam is an advantage for it carries more heat per pound. In the ordinary small steam plant, the quality of the steam will range from 94 to 98 per cent.

**Boilers.**—Boilers used in ice cream plants should be selected after consideration of the size load to be carried, the uniformity of load, and the type of help to operate the boiler. For a plant of small size in which inexperienced, or low-grade help is employed and in which the load is very fluctuating, a horizontal tubular boiler or a Scotch marine type will be found satisfactory. These boilers have the advantages of economy of space and of upkeep. It is also very easily installed or moved as desired. A boiler of this type, having a large water space, will care for fluctuating load conditions much more easily than one whose water space is small. For large plants which employ high-grade engineers and firemen, and in which the load factor is quite uniform, the water-tube boilers are more frequently used, because in the larger sizes they are safer and more efficient than the tubular types. However, they require considerably more upkeep and attention. Their first cost is also higher.

**Fuels and Furnaces.**—The type of fuel used in the plant will depend very largely upon local conditions, prices of fuel, etc. The oil-fired boiler has slightly higher efficiency, is more easily operated, and gener-

ally will handle overloads more quickly and easily than will the coal-fired boiler. However, the latter, when used with the modern automatic stoker, is very efficient and is much used, especially in the eastern states. If the transportation cost is a large part of the total cost of the coal, it will probably pay to use a high quality of coal; while if this is only a small item, a lower quality may be used. Fuel oils should be purchased according to a guarantee of a certain heat value, flash point, and gravity. Considerable saving may be made by purchasing oil in carload lots; often the purchase of a large underground tank which will hold a carload or more of oil is desirable.

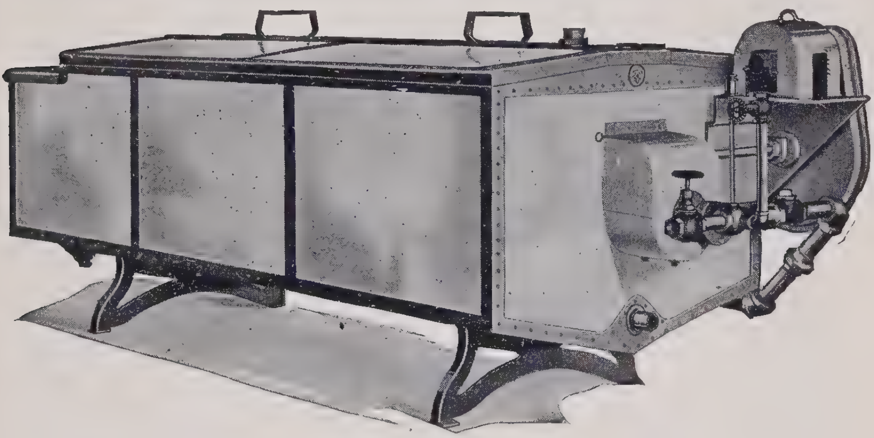
Two common types of oil burners are used throughout the country. The first is that in which heat and pressure are used for vaporizing the oil. With this type, the burner is usually constructed with two connections, one for oil and the other for steam pressure. The oil is forced out through the tip, where it is mixed with steam and blown into a very fine spray. This type of burner operates very satisfactorily and is used in many plants. However, it requires steam or air pressure for starting, and in its operation will use from 2 to 4 per cent of the steam generated by the boiler.

Many of the newer plants use the motor-driven rotary type of oil burner. It may be started almost instantly and requires only a small electric motor for its operation. The efficiency is practically the same as with the other type of burner.

**Steam Piping.**—Steam pipes are usually made of the best grade of wrought iron or of steel with cast-iron fittings throughout. On large pipe, gate valves are used; while on small pipe the globe valve gives less trouble from leakage. Moreover, the seats can be renewed at a nominal cost. All steam lines should be thoroughly insulated. The heat loss from 1 foot of 2-inch steam pipe which is carrying steam at 60 lbs. per square inch pressure, has been measured and found to be approximately 483 B.T.U. per hour, room temperature 70° F., which, with coal at $5 a ton, would amount to a loss of 8.6 cents per month. Practically 95 per cent of the loss may be prevented by proper insulation. Many types of insulation are available; those most commonly used are the magnesia or the asbestos types. Insulation pays, not only from the standpoint of cost of operation but from the increased efficiency of the heating apparatus, since it prevents the condensation of steam in the lines.

**Steam-operated Equipment.**—The principal types of equipment which use steam in the ice cream plant are the hotwells, pasteurizers, can washers, sterilizers, and condensers. Each of these different types of equipment has its own special problems. Certain fundamental principles should be considered with all of them. First, the heating

surface should be large enough to permit the heat to be transferred without using too high temperatures. For instance, if a pasteurizer has insufficient heating surface, it will be necessary to carry the temperature of steam or hot water so high that there will be danger of burning on of solids and of getting a scorched flavor, both of which can be prevented if the heating surface is sufficient, agitation good, and the heating medium is carried at a lower temperature. Second, the temperature of the steam is very largely affected by the pressure. Increasing the pressure of the steam will always increase the temperature to some extent, as shown in the steam tables. Third, the amount of heat given up by the steam in the heater is affected by the quality of the steam.



*Courtesy Creamery Package Mfg. Co.*

Fig. 77.—Horizontal Coil Vat Pasteurizer.

Steam containing moisture has not the heating effect of the dry steam. Fourth, for uniform heating, a good agitation of both the heating medium and the product heated is necessary. Fifth, the thickness and kind of metal used in the wall between the heating medium and the product heated is very important, since the amount of heat carried is determined by the conductivity and the thickness of the wall.

## REFRIGERATION

**Principles of Cooling: Definition of Refrigeration.**—Refrigeration is the taking away of heat units from a body, and is, therefore, concerned with the exchange of heat. Refrigeration is concerned practically with the taking away of heat from cold objects, usually where the temperature is below 40° F. The cooling of milk from, say, 90° F. to 50° F. is also

refrigeration in principle. The ice cream manufacturer is interested in the method of refrigeration, because the principal physical process which takes place is the removal of heat from the ice cream mix. This is done in several different stages. The first operation is the cooling of the milk as it is received in the plant. Next is the cooling from the pasteurizing temperature to the storage temperature. Then comes the extraction of part of the heat in the mix in the freezer, and finally, the further extraction of heat and hardening of the ice cream in the hardening room. It may be assumed that one-half of the heat of fusion of the mix is removed in the freezer. The ice cream manufacturer, therefore, is primarily interested in the production of low temperatures between the ranges of 35° F. and 0° F. He is also interested in the cooling of brine, which is often used in the operation of the freezer and for cooling the mix.

**Cooling with Ice and Salt.**—Two methods of refrigeration are employed in the ice cream plant; namely, the use of ice and salt, and mechanical refrigeration. In the use of ice and salt, Bowen[1] has made an exhaustive study of the temperatures obtained and the ratio of ice and salt required. Where a small amount of refrigeration is required, as in the packing of ice cream cans during transportation and in certain small plants where a hardening room is not available, the ice-and-salt method of freezing may be used. The temperature obtained by an ice-and-salt mixture depends almost wholly upon the relative proportions of ice and salt, and to a certain extent on the rate at which heat is supplied from the outside. The density of the brine and the size of the ice and salt particles also have some effect on the temperature. For quick freezing, the ice should be in small lumps and the brine should be relatively strong. It is impossible to give other than approximate temperatures with fixed ratios of salt and ice, because of variations in the above factors.

From the curve in Fig. 78, the approximate temperatures resulting from different proportions, by weight, of ice and salt may be obtained. For example, if it is desired to produce a temperature of 5° F., the proportions of ice and salt may be determined from the curve as follows: The horizontal line marked 5° at the point where it cuts the curve shows that the percentage of salt, by weight, would be approximately 16. Table LXXXIII also shows the approximate temperatures obtained with different proportions of ice and salt.

The further action of the ice and salt in producing the low temperature may be explained as follows: Ice always has a certain film or moisture on its surface, which, if brought in contact with salt, dissolves the latter and forms a brine. In doing this a certain amount of moisture

[1] U. S. D. A. Bul. 98.

is literally pulled out of the ice by the attraction of the salt for the moisture. In order that this moisture may be removed from the ice,

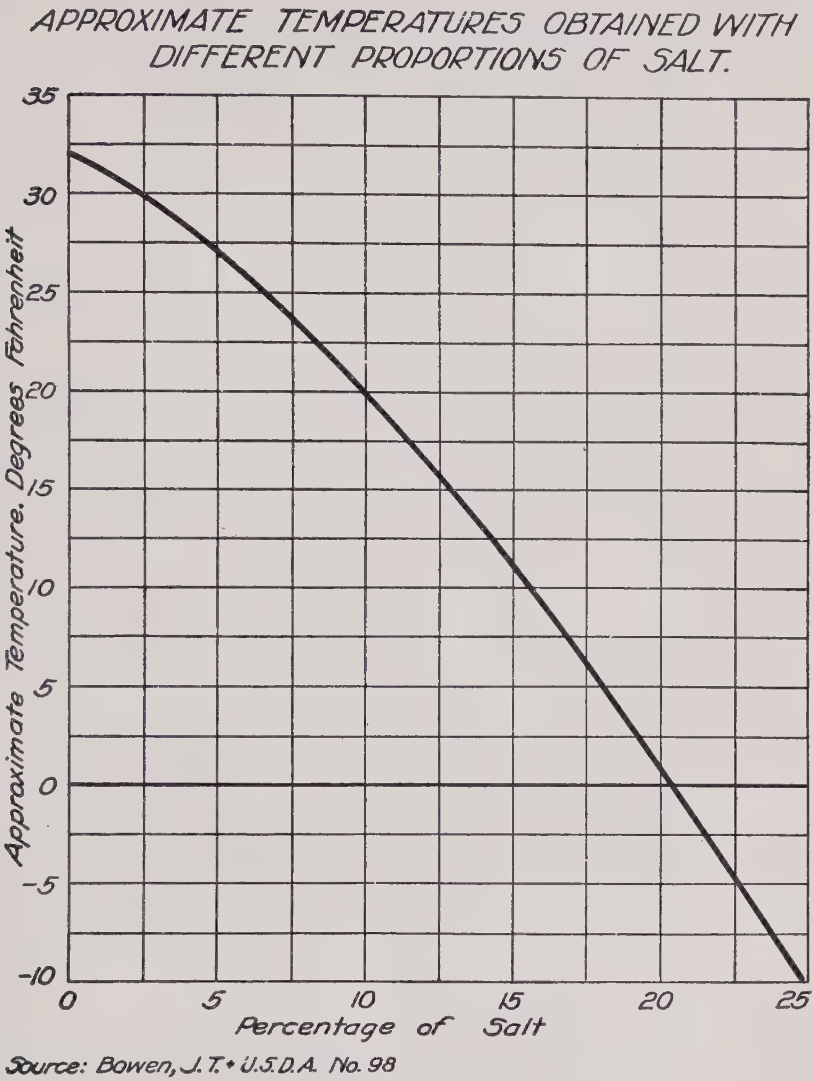



FIG. 78.

heat must be added. For every pound of ice that is changed into water, 144 B.T.U. are absorbed. This heat must come from the ice, salt, and resulting brine. Therefore, the temperature of these parts is reduced.

This process continues as long as there is heat available to be absorbed by the ice or until the temperature is reduced to the point where the brine and salt are no longer able to attract the moisture from the ice.

TABLE LXXXIII

| Per Cent of Salt in Mixture | Temperature of Mixture ° F. | Per Cent of Salt in Mixture | Temperature of Mixture ° F. |
|---|---|---|---|
| 0 | 32 | 15 | 11 |
| 5 | 27 | 20 | 1.5 |
| 10 | 20 | 25 | −10 |

There is also some cooling action due to the solution of the salt itself in water. This varies from 58 to 16 B.T.U. per pound of salt, depending upon the final strength of the brine obtained. Table LXXXIV gives the heat of solution of one pound of salt dissolved in water at 32° F., up to the concentration given by the number of pounds of salt dissolved in 100 lbs. of water.

TABLE LXXXIV *

Refrigeration Available with Different Proportions of Ice and Salt

| Salt per 100 Pounds Water | Heat of Solution per Pound of Salt | Total Heat of Resulting Solution | Heat Required per Pound of Mix | Salt per 100 Pounds Water | Heat of Solution per Pound of Salt | Total Heat of Resulting Solution | Heat Required per Pound of Mix |
|---|---|---|---|---|---|---|---|
| Pounds | B.T.U. | B.T.U. | B.T.U. | Pounds | B.T.U. | B.T.U. | B.T.U. |
| 1 | 58.0 | 14,458 | 143.0 | 20 | 27.0 | 14,940 | 124.5 |
| 5 | 49.7 | 14,668 | 139.5 | 25 | 22.5 | 14,962 | 119.5 |
| 10 | 40.5 | 14,806 | 134.5 | 30 | 19.1 | 14,973 | 115.0 |
| 15 | 33.0 | 14,895 | 129.5 | 35 | 16.4 | 14,974 | 111.0 |

* U. S. D. A. Bul. 98, Bowan, J. T., p. 15.

The curve in Fig. 79, based on the percentage of salt, shows the amount of refrigeration available per pound of ice-and-salt mixture. Certain corrections should be made for the temperature of the ice and salt, if accurate results are to be obtained. If the salt is added to the ice at a temperature varying from 32° F., or if the resulting brine is allowed to escape at a temperature other than 32° F., the amount of available refrigeration should be corrected as follows: The weights in pounds of

salt and brine should be multiplied by their respective specific heats and by variation of their respective temperatures from 32° F. The specific

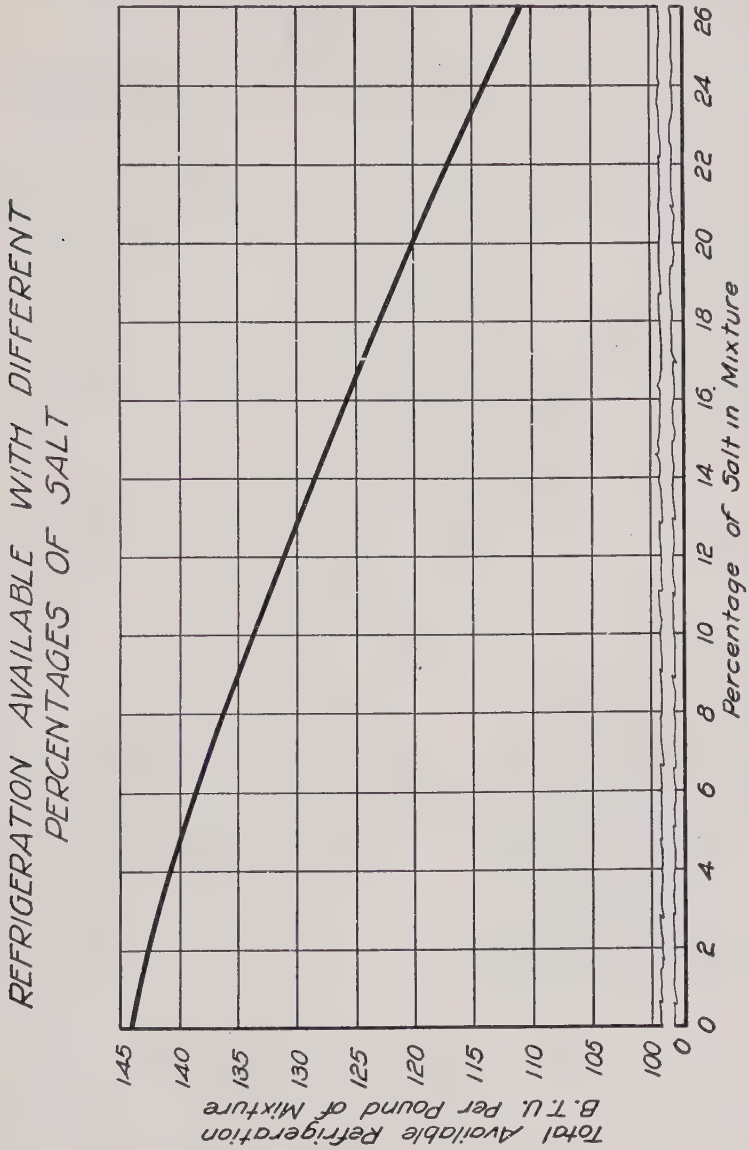



FIG. 79.

heat of dry salt may be taken as 0.214, that of salt brine may be obtained from Table LXXXVIII, which shows the freezing point and specific heat of various concentrations of salt brine.

Usually, when salt is added to ice it is of a higher temperature than the ice. Consequently, the correction for a heat above 32° F. must be subtracted from the available refrigeration shown by the curve in Fig. 79; and if the brine is allowed to escape at a temperature below 32° F., the discharge must be subtracted. On the other hand, if the discharge temperature is at a higher temperature than 32° F., the correction must be added.

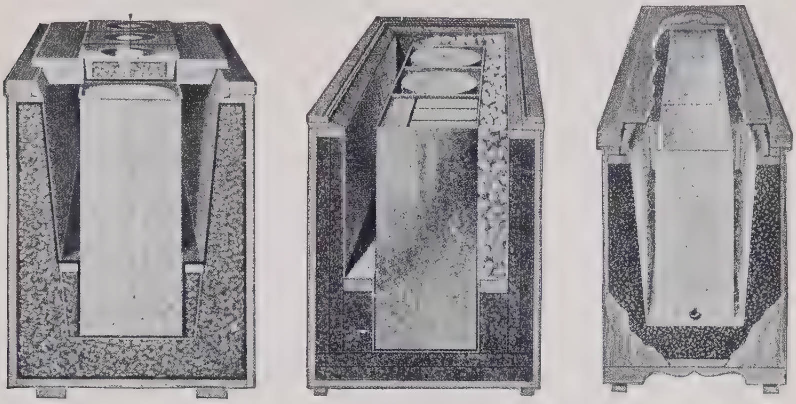
As an example of the application of ice and salt to a practical problem, let it be required to find the available refrigeration produced when 100 lbs. of dry salt are added to 900 lbs. of ice. In solving this problem, the total weight of the resulting brine will be the weight of the salt plus the weight of the ice, or 1000 lbs. The total available refrigeration per pound of moisture, as shown in Fig. 79, is 132 B.T.U. Therefore, the total available refrigeration would be $1000 \times 133 = 133{,}000$ B.T.U. If the salt added is at a temperature higher than 32° F., say 60° F., then the available refrigeration will be $133{,}000 - (100 \times 0.214\ (60 - 32)) = 132{,}401$ B.T.U. If the resulting brine is allowed to escape at 25° F., the available refrigeration is $133{,}000 - (1000 \times 0.892\ (32 - 25)) = 126{,}756$ B.T.U. In other words, by adding the salt at a higher temperature, 599 B.T.U. were lost, while by allowing the brine to escape at 25° F., 6244 B.T.U. were lost.

In the cooling of ice cream packers by the ice-and-salt method, it is very desirable to crack the ice uniformly fine, if low temperatures are desired. It is also necessary to mix the salt uniformly through the mixture. Otherwise, unevenness in cooling will result. Where ice and salt are used for cooling ice cream truck bodies, the same considerations hold. In this case, however, it is necessary to stir up the ice-and-salt mixture occasionally with a hoe or some similar device, in order to prevent the salt from settling down to the bottom of the ice-and-salt compartment. Temperatures can be controlled practically, both by the proportion of the ice and salt, the fineness to which the ice is cracked, and the uniformity of distribution of the salt through the mixture. In any kind of an ice type of cabinet, or truck body, the insulation of the body is one of the most important considerations. A good insulation is necessary for economical results. The National Association of Ice Cream Manufacturers have lately made an investigation of the cost of

*Courtesy Cochrane Corporation*

FIG. 80.—Cutaway of Ice Breaker.

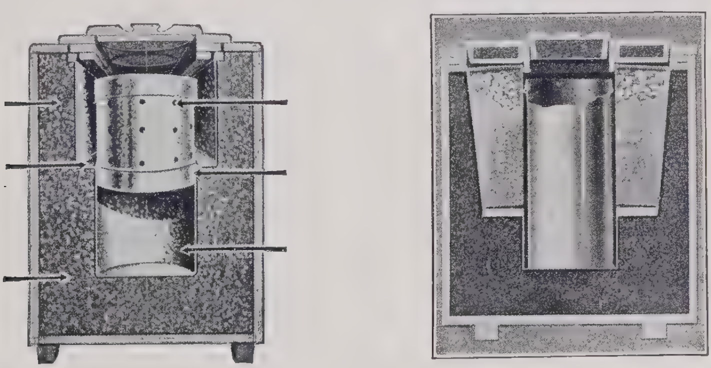
operation and temperatures obtained in ice-and-salt cabinets of different types. The following conclusions, as a result of their investigation, are important. An ice cream can in a square compartment (dry pack)



*Courtesy Olsen Publishing Co., Ice Cream Review*

Fig. 81.—Three Types of Dry Pack Ice and Salt Cabinets.

shows less fluctuation in the temperature of the ice cream from hour to hour and from day to day, and also less difference in temperature between the top and bottom of the can. A can containing ice cream directly in



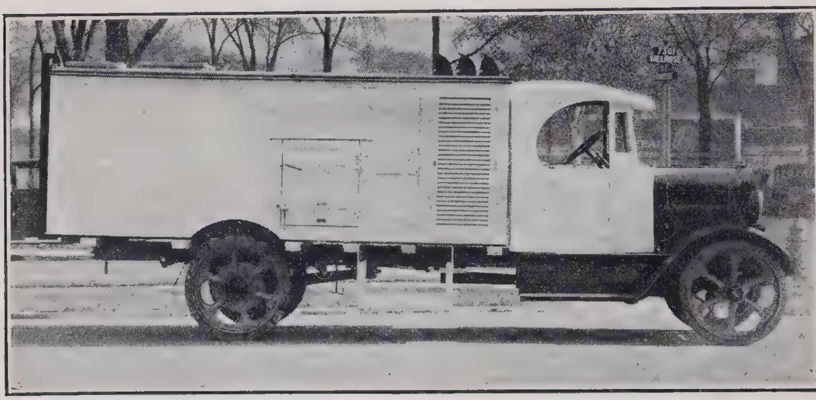
*Courtesy Olsen Publishing Co., Ice Cream Review*

Wet Pack Cabinet. Tray Pack Cabinet.

Fig. 82.

contact with the ice-and-salt has a very great difference in the temperature between the top and bottom of the can, especially just before the re-icing, when the ice has melted and fallen below the level of ice cream. In the square compartment, the frost from condensation forms

on the inner surface and does not get into the ice cream can as it does in the wet-pack method. The square compartment extending up to the under side of the cover prevents the heat which leaks through the walls from reaching the ice cream, and thus making it soft on top. The results obtained by the National Association of Ice Cream Manufacturers showed that the 4 to 1 ratio of ice to salt was most efficient, that the "emulsing method" of icing cabinets should be used by manufacturers to assure uniform packing and prevent damage to cabinets, and that it pays to buy well-insulated cabinets which require re-icing only once every forty-eight hours. They found that different ice creams require different temperatures. Every manufacturer should experiment until he arrives at the proper proportion of ice and salt for his particular



*Courtesy Frigidaire Corporation*

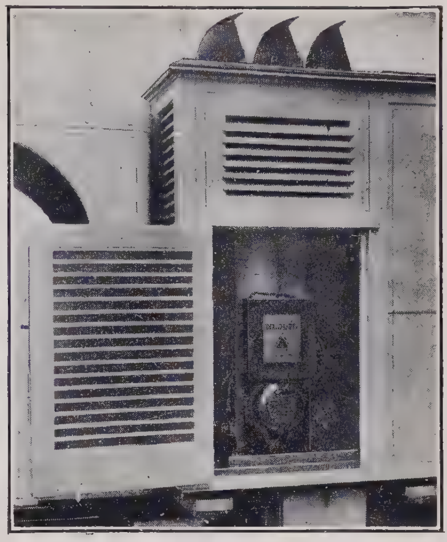
Fig. 83.—Modern Ice Cream Truck Equipped with a Small Refrigerator.

type of ice cream. The amount of ice and salt used per gallon per forty-eight hours in the cabinets varied from 31.3 to 85.2 lbs. The salt varied from 6.4 to 13.1 lbs. per gallon of ice cream.

**Refrigerated Trucks.**—The transportation of ice cream also involves the use of trucks. Many different types have been tried and, until 1926, most trucks were refrigerated by means of ice and salt, having a compartment in which the ice cream cans could be stored during transit, and which was cooled by brine pipes. With this type of truck it is usually necessary to add a considerable amount of ice each day and to stir up the old ice and salt. Many operators used a hoe-shaped instrument for the latter purpose.

During 1926, a number of trucks were built with a small ice cream cabinet type of mechanically refrigerated machine for cooling the cold-storage compartment. In one particular outfit, the motor of the

refrigeration machine was driven by electricity generated by means of a farm lighting plant, which was installed on the truck. The temperatures were maintained by means of a thermostat, which controlled the starting and stopping of the plant.

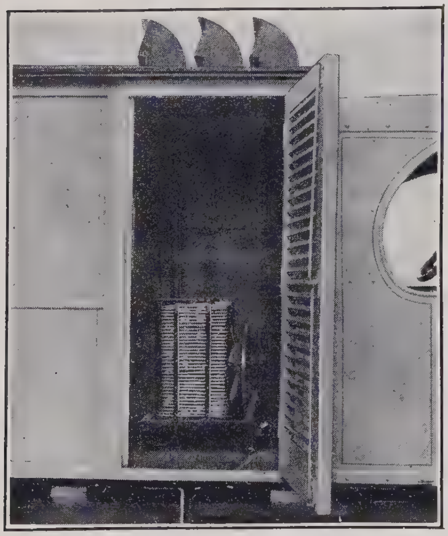


Courtesy Frigidaire Corporation

FIG. 84.—Automatic Generator on the Truck Furnishes Power to Operate the Refrigerator Unit.

As a practical demonstration of what this truck would do, ice cream carried from Los Angeles to San Francisco, to the Pacific Slope Dairy Show, during November, 1926, was maintained in perfect condition.

**Shipping Jackets.**—Insulated shipping jackets made of felt or some other insulating material and so constructed that the ice cream cans may be slipped into them, are used in many plants. They are satisfactory for hauls of short distance, where the total time during transit is not over three or four hours. Under some conditions, they may serve for a longer period of time.



Courtesy Frigidaire Corporation

FIG. 85.—The Refrigeration Unit in the Truck is Similar to those in Iceless Cabinets.

They have a number of advantages over the ice-and-tub method, since they are very light, there is no salt, ice, or water to contend with, and they are easily handled. They are of particular value in connection with the use of iceless cabinets, since if they are cooled well before shipping, the ice cream can then be placed in the cabinets

absolutely dry and will not slop water over the fixtures in the retail store.

**Dry Ice.**—Experiments have been conducted recently with a view to making practical the use of frozen carbon dioxide, sometimes called "dry ice."

This material is merely a solid, frozen, compact carbon dioxide snow formed by the cooling of liquid carbon dioxide below its freezing point. The material has practically twice the refrigerating value, pound for pound, of water ice, and has a temperature of − 114° F. At the freezing temperature, 0.014 cu. ft. of the material weighs one pound, or, in other words, one cubic foot weighs 70–100 lbs., depending upon how well it is compacted.

Experiments conducted so far have shown that very low temperatures may be obtained and that the material may be shipped long distances with very small losses, when containers are properly insulated. As ordinarily used, the material is packed in the form of small cubes or blocks and set in the container along with ice cream or other products which are to be kept cold. As the carbon dioxide vaporizes, it takes up heat and refrigerates the bag.

The principal advantage in its use is that it vaporizes as fast as it melts, thereby doing away with the moisture incurred when water ice melts.

## Mechanical Refrigeration

Mechanical refrigeration is based upon the principle that a liquid absorbs heat when it vaporizes. The heat that is absorbed is called latent heat and corresponds to the heat absorbed by water when it is changed into steam. A medium other than water must be used, as water will not vaporize except at temperatures around 212° F. or higher at ordinary pressure. There are a number of substances, such as ammonia, methyl chloride, sulphur dioxide, carbon dioxide, and others, which vaporize readily at temperatures below freezing; these are made use of in a practical way in mechanical refrigeration. It is first necessary, however, to define the units in which refrigeration is measured. The term "ton refrigeration" is a cooling equivalent to the heat absorbed by the melting of one ton of ice without change of temperature and is equivalent to the absorption of 288,000 B.T.U. A one-ton refrigeration machine will produce one ton of refrigeration in twenty-four hours' continuous operation under a stated set of conditions. An ice machine is usually rated at half the size of the refrigeration machine, since practically 2 tons' refrigeration are required to freeze one ton of ice under commercial conditions.

**Refrigerants.**—The refrigerant to be used in the operation of a

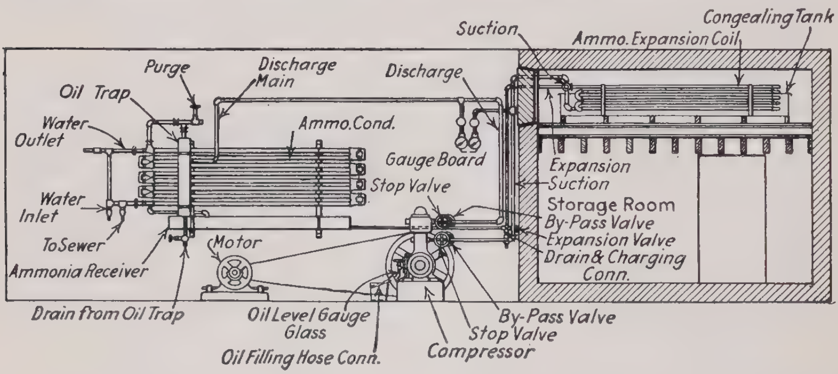
refrigeration machine involves the consideration of a number of points. A good refrigerant should have a low boiling point at ordinary pressure, a large heat of vaporization, and a small specific volume. A low boiling point is desirable because it makes operation possible with a comparatively low pressure in all parts of the system. Therefore, the machine and accessories may be of lighter construction with smaller loss of gas by leakage. The latent heat of vaporization, to a certain extent, is a direct measure of the cooling effect; and the greater the heat of vaporization, the fewer the pounds of refrigerant that must be circulated. The smaller the specific volume of the refrigerating agent, the smaller the size of the cylinders of the compressors and, therefore, the size and weight of the machine used. For large refrigeration machines, the three agents most commonly used are ammonia, carbon dioxide, and sulphur dioxide; in the small machines used in cooling iceless cabinets, methyl chloride and ethyl chloride are sometimes used. All of these refrigerants are similar in the way they vaporize and act in the refrigeration machine. There is a great difference, however, in the pressure at which they operate and their effect upon metals and the ease with which leaks may be detected, also their poisonous properties, if any.

For practical purposes, the value of the refrigerant depends upon the boiling point, its latent heat of vaporization, and the pressure at which it can be used. To obtain a zero temperature with ammonia as a refrigerant, an approximate pressure of 15 lbs. per square inch gauge pressure is required in the evaporating coils; with carbon dioxide, 295 lbs. gauge pressure; and for sulphur dioxide, $-5$ lbs. Ammonia has a much greater latent heat of vaporization, and its working pressures are not excessive; its principal disadvantage is that it corrodes brass or other copper alloys. Consequently, only iron or steel can be used in the construction of those parts of the machine with which the agent comes in contact. The pressures of carbon dioxide are so high as to cause occasional trouble in keeping the stuffing box and joints tight. A relief valve is often placed in the high-pressure side of the system in order to protect it from the excessively high pressures. It is non-corrosive, non-explosive, and is not dangerous to life when diluted with air. The high pressures necessary, combined with its small specific volume, make it suitable for use with a very small compact machine. As the low pressure of sulphur dioxide is below atmospheric, leakage of air may bring in moisture and may cause corrosion of the metal by forming sulphurous acid. The low pressures required when using sulphur dioxide as a refrigerant, together with its large specific volume, make a large and cumbersome machine necessary.

Methyl chloride is a colorless, sweet-smelling gas, which is obtained

by the action of hydrochloric acid on methyl alcohol. It is easily liquefied and has a boiling point of $-10.65°$ F. at atmospheric pressure. It is inflammable in concentrations of at least 10 per cent, and not more than 15 per cent with air. It does not attack copper, copper alloys, or iron. Methyl chloride operates with a pressure greater than atmospheric, on both the condensing and evaporating units of the system. The pressure and specific volume of methyl chloride are very nearly the same as those of sulphur dioxide.

**The Compression Refrigeration System.**—The compression refrigeration plant, illustrated in Fig. 86, consists of several essential parts: *The compressor* is a high-pressure pump, which draws the vaporized refrigerant from the evaporating coils, compresses it, and then forces it into the condenser. During this operation the gas is reduced in volume




*Courtesy York Products Company*

FIG. 86.—Diagram of Compression Type Refrigeration Machine.

and its temperature is raised. *The condenser* consists of a series of coils of pipe, through which the compressed vapor is allowed to flow and through the walls of which the heat is given off to cooling water or to cooling air. The heat contained in the gas is thereby given up and the gas liquefied. The liquid refrigerant then passes down to the receiver. *The receiver* is a tank in which the liquid refrigerant is held in storage until it is needed in the evaporator. *The evaporator, or expansion coil,* is a series of pipe coils into which the liquid refrigerant is allowed to vaporize after going through the expansion valve; it is here that the heat is absorbed by the refrigerant. As the absorption takes place, heat is taken out of the cold-storage room or brine tank and causes the liquid refrigerant to be vaporized. Each pound of liquid absorbs a certain amount of heat. This vapor is then drawn into the compressor and the cycle repeated.

The process of refrigeration by the compression system may be divided into three distinct stages: compression, condensation, and vaporization. During compression, the gaseous refrigerant is drawn into the compressor or pump and there compressed to a pressure dependent upon the kind and amount of refrigerant and the temperature and quantity of cooling water used in the condenser. The temperature of the refrigerant is raised and a part of the heat of vaporization converted into sensible heat at this stage of the cycle. During condensation, the vapor is forced into the condenser coils under high pressure, by the compressor, where the sensible heat developed during compression is removed by the cooling water, thereby reconverting the refrigerant into a liquid at the temperature and pressure existing in the condenser. The vaporization of the refrigerant occurs after it has left the liquid receiver, passed through the expansion valve, and entered the expansion coils. The pressure in the expansion coil is much lower than that in the condenser and receiver; this causes an immediate expansion of the refrigerant, which is augmented by the heat absorbed through the walls of the expansion coil which vaporized the liquid.

**The Capacity of Refrigeration Machines.**—The expansion coils must be large enough to absorb the required amount of heat; the compressor must be large enough to pump all of the vapor formed in the expansion coil into the condenser and must be of sufficient size easily to transfer the heat absorbed in the expansion coil to the cooling water.

The amount of surface of the condenser, together with the amount and temperature of the cooling water, are especially important from the standpoint of cost of operation, since with insufficient cooling capacity the refrigerant will be liquefied with difficulty, and as a result the compressor must operate against a high pressure. This causes a high power consumption. An investigation conducted at the University of California showed that the energy consumed by a refrigeration plant was reduced approximately 16 per cent by reducing the head pressure from 200 lbs. per square inch to 150 lbs. Often the installation of more compressor surface or the use of more cooling water will be found to pay for itself in a short time through lower power cost. At the same time, the wear and tear on the refrigeration machine is reduced, since the pressures will be lower. The pressure on the high side of the machine does not materially affect the capacity of the machine. This is not true, however, of the pressure on the low side or expansion coil. The lower the pressure on the low side, the more cubic feet of refrigerant must be pumped for a certain amount of refrigeration. Thus, with a back pressure of 6 lbs. absolute, 5.58 cu. ft. of gas must be pumped per minute

to make a ton refrigeration per twenty-four hours, while with 24 lbs. back pressure, only 2.99 cu. ft. must be pumped.

Refrigeration machines are usually rated at so many tons refrigerating capacity when operating at a given back pressure of either 16 lbs. or 25 lbs. If the operating back pressure is greater than that rated, the machine will have more capacity; if it is operated at a lower back pressure, however, its capacity will be much reduced. This explains why it is a good plan in an ice cream factory to have two separate refrigeration systems, one operating at low pressure to handle the brine and hardening room or other extremely low temperatures, while the second, operating at a higher back pressure, carries the higher temperatures. This method makes possible a much greater efficiency in the handling of the rooms of higher temperature. In actual practice, a 25-ton refrigeration machine rated at a 25-lb. back pressure and operating at 16 lbs. would have only approximately 20 tons' capacity.

TABLE LXXXV

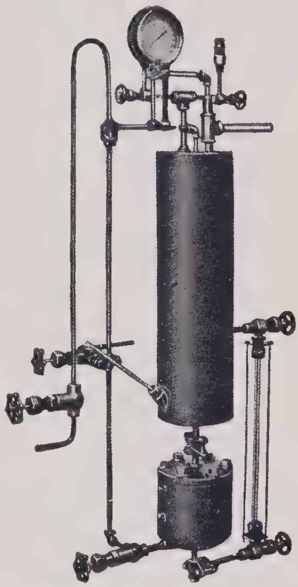
Effect of Back Pressure upon the Capacity of Refrigeration Machines

| Back Pressure | Head Pressure | Capacity in Tons | Horse Power per Ton |
|---|---|---|---|
| 5 | 150 | 8.40 | 1.87 |
| 10 | 150 | 10.68 | 1.60 |
| 15 | 150 | 12.30 | 1.40 |
| 20 | 150 | 14.70 | 1.30 |

The flooded system of refrigeration in brine tanks is much more efficient than the plain system, because of the fact that heat is transferred much more readily between liquids than between liquids and gases. For those who have trouble in holding the temperatures in their brine tanks because of insufficient coil surface and are not now using the flooded system, its use is to be recommended.

In connection with the flooded system, however, it is necessary to use an accumulator. This is merely a trap which collects any liquid refrigerant that may be in the ammonia return line and directs it back into the bottom of the refrigerating coil instead of allowing it to pass on into the compressor. Its use makes possible a higher operating efficiency and reduces to a minimum the danger of liquid getting into the compressor.

Certain known condensable gases, such as air, which may leak into the system through stuffing boxes or fittings, and hydrogen and nitrogen, which may result from decomposition of ammonia, tend to accumulate in the condenser, and unless removed, will occupy space which should be used by the ammonia. This causes the head pressure to build up and results in inefficient operation. These gases should be removed by pumping, which is merely the operating of a vent attached to the condenser, or by using a known condensable-gas remover such as is illustrated in Fig. 87. (Courtesy York Mfg. Company.)



*Courtesy York Products Company*

FIG. 87.—This Non-condensible Gas Remover Automatically Removes Foul Gases from the Refrigeration System, Thereby Decreasing the Head Pressure.

**Cold-storage Boxes.** — Cold-storage rooms for ice cream plants might be divided into two groups: those of medium temperature, used for general cold storage; and those of very low temperature, used in hardening the ice cream after it has been drawn from the freezer. While rooms of medium temperature present no special difficulties, they should be well insulated and, if possible, should be so arranged that they surround those of lower temperature. Care should also be taken to locate these rooms so that they will be as convenient as possible. The hardening room presents several problems because of the low temperatures involved and the necessity for building it compactly and at the same time make the handling of the ice cream as easy as possible. Perhaps one of the most important factors of the hardening room is the insulation. This insulation should be of cork board at least 8 inches thick, and might well be 10 inches unless the room is surrounded by other cold-storage rooms, in which case the thickness may be decreased somewhat. A common practice is to build the long end narrow, with an aisle in the center and shelves on each side. This arrangement makes the placing and removal of ice cream cans very simple. In some of the larger plants, the room is made square and divided into long narrow sections similar to the type first mentioned. The room should be made no higher than necessary, and, in the case of large rooms, the nearer the room approaches a perfect square, the better, since the proportional wall area to cubic content is decreased in this manner.

The expansion coils are often placed in the cold-storage room itself and may form the shelves upon which the ice cream is set. This method has certain advantages: namely, those of making possible the placing of the large amount of expansion coil necessary and of bringing the cold pipe very close to the ice cream which is to be hardened. The direct-expansion method of refrigeration is nearly always used in hardening rooms. Again, the expansion coils are sometimes placed in a very compact compartment, the air from the hardening room being circulated through these coils and back into the hardening room. This method operates quite efficiently and has the advantage of keeping the pipes out of the hardening room, giving a neater appearance and a room that is more easily kept clean. Another advantage of this system is that, because of the action of the fan in moving the air, there is often a better circulation of air with correspondingly more uniform temperatures.

The following factors should be considered in building a cold-storage room and are especially necessary in the construction of cold-storage rooms in the ice cream plant. First, the room should be strong and durable. A reinforced concrete construction, together with cork-board insulation, presents one of the best types of construction, as it has both mechanical strength and durability. Certain types of insulation, like sawdust, should not be used with low-temperature rooms. Second, the room should be fireproof. Third, ventilation is important, as a periodic changing of the air in the rooms is necessary from the standpoint of sanitation and the proper keeping of products. In small rooms, ventilation is accomplished by the opening and closing of doors, but in the large rooms a forced ventilation is necessary. Drainage of floors is also essential, especially in rooms that are carried at temperatures above 32° F. This is necessary both for carrying off water when cleaning up the room and also for disposing of spilled products. Often, drainage is best obtained by placing an ordinary trap in the center of the room and having the floor slope toward this place. Another method is to have the entire floor slope toward the door. Bunkers, which are merely catch basins fastened under the expansion coils, should be used in all rooms having temperatures above 32° F., because the moisture which condenses from the pipes will be continually dripping down upon the floor of the room. Tight doors are necessary for the best results, as cold air will leak out of a poorly fitting door or an opening, in exactly the same manner in which water would leak out of a tank. Tight doors can best be obtained by having the door well made and fitted with a good gasket. Windows should not be placed in cold-storage rooms, as they cause leakage of air and heat; better illumination can be obtained by the use of electric lights. Baffles should be so placed that they assist the

natural circulation of air in the room. A very common practice is to place them immediately in front of the expansion coils which are located on the side walls. It should be mentioned that it is generally considered better practice to place the expansion coils near the top of the room rather than on the side walls.

Perhaps the most important feature of a cold-storage room is the insulation in the walls. The purpose of most of the refrigeration added to a cold-storage room is to overcome the heat which leaks in through the walls. The total refrigeration necessary for a room is, first, that necessary to cool down the products stored; second, that necessary to overcome air leaks; and third, and most important, that necessary to overcome heat leakage through the walls. This cannot be stopped entirely, but the use of good insulation will lessen it. The heat-transferring capacity of a *wall* is usually figured as the number of B.T.U. transmitted per twenty-four hours per square foot area per degree F. difference in temperature in the two sides of the wall. Insulation material, with reference to refrigeration practice, must be a poor conductor of heat, as this is its principal purpose. Second, it should not be unstable, like sawdust, for instance, which settles after several years and leaves a portion near the top of the wall without insulation. Third, the insulation should be waterproof, as there is a tendency for cold objects to condense and absorb moisture. Water is a relatively good conductor of heat compared to insulating materials; therefore, a water-soaked insulation is a good conductor of heat and a poor insulator. Fourth, the insulation should be tight. Cracks in the insulation allow entrance of air, carrying with it moisture which soon freezes and not only makes a fairly good conductor but may even pull the insulation out of place. On brine pipes, for instance, a small leak may allow air to enter. The moisture accumulates and freezes until the insulation is actually pushed away from the pipe, leaving a large opening. Fifth, a fireproof insulation is quite important, since it reduces the fire hazard. Sixth, permanency is a desirable quality, since renewing insulators is a very difficult and expensive undertaking. Seventh, insulation should be odorless, as ice cream has the property of absorbing odors. Any strong odor would thus cause trouble.

The insulating value of *materials* is rated according to the number of B.T.U. transferred in twenty-four hours per square foot area per inch thickness per degree F. difference in temperature. Table LXXXVI gives the conductivity of a number of the more commonly used substances.

The conductivity of a wall is inversely proportional to its thickness. That is, if a wall has 1 inch of cork insulation, its conductivity is 7.4 B.T.U.; if it were made of 2 inches of cork, the conductivity would be

TABLE LXXXVI *

THERMAL CONDUCTIVITIES OF VARIOUS INSULATING AND BUILDING MATERIALS

(Adapted from the United States Bureau of Standards Tables)

| Material | Remarks | Thermal Conductivity C | Density D |
|---|---|---|---|
| Air | If no heat is transferred by radiation or convection | 4.2 | 0.08 |
| Calorox | Fluffy mineral powder | 5.3 | 4.0 |
| Kapok | Hollow vegetable fibers loosely packed | 5.7 | 0.88 |
| Pure wool | | 5.9 | 6.9 |
| Pure wool | | 5.9 | 6.3 |
| Hair felt | Fibers perpendicular to heat flow | 5.9 | 17.0 |
| Pure wool | | 6.3 | 5.0 |
| Slag wool | Loosely packed | 6.3 | 12.0 |
| Keystone hair | Hair felt and other fibers confined with building paper | 6.5 | 19.0 |
| Mineral wool | Loosely packed | 6.5 | 12.0 |
| Cork board | No artificial binder, low density | 6.5 | 6.9 |
| Mineral wool | Fibers perpendicular to heat flow | 6.9 | 18.0 |
| Cotton wool | Medium packed | 7.0 | 5.0 |
| Pure wool | Very loose packing, probably air circulation through material | 7.0 | 2.5 |
| Insulite | Pressed wood pulp | 7.1 | 12.0 |
| Mineral wool | Firmly packed | 7.1 | 21.0 |
| Linofelt | Vegetable fiber confined with paper. Flexible and soft | 7.2 | 11.3 |
| Ground cork | Less than 1/16 inch | 7.1 | 9.4 |
| Cork board | No artificial binder | 7.3 | 9.9 |
| Cork board | No artificial binder | 7.4 | 11.3 |
| Sil-O-Cel | Pulverized | 7.4 | 10.6 |
| Regranulated cork | About 3/16 inch | 7.5 | 8.1 |
| Balsa wood | Very light wood, across grain | 7.5 | 7.1 |
| Balsa wood | Same sample with 13% waterproofing compounds | 8.3 | 8.0 |
| Cotton seed hull fiber | Loosely packed | 7.5 | 4.4 |
| Cabots quilt | Eel grass enclosed in burlap | 7.7 | 16.0 |
| Flaxlinum | Felted vegetable fibers | 7.9 | 11.0 |
| Fibrofelt | Felted vegetable fibers | 7.9 | 11.0 |
| Rock cork | Mineral wool and binder | 7.9 | 16.0 |
| Ceiba wood | Across grain—untreated | 7.9 | 7.1 |
| Balsa wood | Across grain—untreated | 8.3 | 7.4 |
| Burrash | Confined with cloth | 8.1 | 8.8 |
| Cork board | With bituminous binder | 8.4 | 16.0 |
| Wood felt | Flexible paper stock | 8.7 | 21.0 |
| Lithboard | Mineral wool, vegetable fibers and binder | 9.1 | 12.5 |
| Balsa wood | Medium-weight wood | 9.2 | 8.8 |
| Sawdust | Various | 9.7 | 12.0 |
| Planer shavings | Various | 10.0 | 8.8 |
| Wall board | Stiff pasteboard | 12.0 | 43.0 |
| Air cell, ½ inch | Corrugated asbestos paper enclosing air spaces | 11.0 | 8.8 |
| Air cell, 1 inch | Corrugated asbestos paper enclosing air spaces | 12.0 | 8.8 |
| Asbestos paper | Built of thin layers | 12.0 | 31.0 |
| Zinitherm | Infusorial earth and asbestos | 12.0 | 16.0 |
| Magnesia 85% | Magnesia and asbestos | 12.0 | 19.0 |
| Insulex | Asbestos and plaster blocks very porous | 13.5 | 18.0 |
| Sil-O-Cel | Infusorial earth, natural blocks | 14.0 | 28.0 |
| Sil-O-Cel | Infusorial earth, natural blocks | 15.0 | 31.0 |
| Balsa wood | Heavy | 14.0 | 20.0 |
| Fire felt sheet | Asbestos sheet coated with cement | 14.0 | 26.0 |
| Fire felt roll | Flexible asbestos sheet | 15.0 | 43.0 |
| Cypress | Across grain | 16.0 | 29.0 |
| Fuller's earth | | 17.0 | 33.0 |
| Asphalt roofing | Felt saturated with asphalt | 17.0 | 55.0 |
| White pine | Across grain | 19.0 | 32.0 |
| Asbestos mill board | | 20.0 | 61.0 |
| Mahogany | Across grain | 22.0 | 34.0 |
| Virginia pine | Across grain | 23.0 | 34.0 |
| Oak | Across grain | 24.0 | 38.0 |
| Maple | Across grain | 27.0 | 44.0 |
| Sole leather | | 26.0 | 62.0 |
| Rubber | Soft vulcanized | 29.0 | 69.0 |
| Textan | Rubber composition | 28.0 | 81.0 |
| White celluloid | | 35.0 | 88.0 |
| Paraffine | "Parawax" melting point 52° C | 38.0 | 56.0 |
| Gypsum plaster | | 56.0 | 46.0 |
| Asbestos wood | Asbestos and cement | 65.0 | 123.0 |

C—Thermal conductivity in B.T.U. per day (24 hours) per square foot per degree F. per inch thickness.

D—Density in pounds per cubic foot.

* Bowen, J. T., Dairy Engineering, pp. 424–425. John Wiley & Sons, Inc., New York.

7.4 divided by 2, or 3.7 B.T.U. The thickness to which walls are insulated is an economic question depending upon the difference in temperature between the cold-storage room and the outside, or the kind of products handled, the cost of refrigeration, and the cost of insulation. Platitudinous as it may sound, it is always better to over-insulate than to under-insulate. The walls for a medium temperature difference should have a conductivity of 2 B.T.U. Walls of a high temperature difference should have a conductivity of 1–1½ B.T.U. Table LXXXVII shows the approximate thickness of insulation which should be used with rooms of various temperatures under average conditions; hardening rooms excepted.

TABLE LXXXVII

Relation between Temperature and Insulation

| Temperature of Room, ° F. | Thickness of Insulation, Inches |
|---|---|
| −20 to −5 | 8 |
| − 5 to +5 | 6 |
| + 5 to +20 | 5 |
| +20 to +35 | 4 |
| +35 to +45 | 3 |
| +45 and above | 2 |

The cost of insulation will be approximately 50 per cent of the total cost of the room, although on hardening rooms it may be slightly more. Sheet cork, which is a very desirable type of insulation, at present prices should cost somewhere in the neighborhood of 10 cents a board foot. Moulded-cork pipe covering for 1-inch pipe should cost from 60 to 75 cents a running foot.

For various types of work, the following kinds of insulation may be used: for walls and flat surfaces, slab cork or, as commonly called, cork board; for pipes, a moulded type of insulation which fits the shape of the pipe very closely; for brine tanks, granulated cork.

In the application of insulation, the following points should be considered. If the insulation is of a granular structure, it should be well packed so that it will not settle. Second, any type of insulation should be made absolutely waterproof. Waterproofing can best be done by setting the material in hot asphalt or in a waterproof cement, or by the use of waterproof paper. Asphalt is not as good as waterproof Portland cement for places in which the walls may become heated from the sun or from too close proximity to the boiler rooms, as the material has a

tendency to melt and settle to the bottom, leaving an open place above. The finishing coat of a cold room may be a heavy coating of waterproof paint or a cement plaster which has been waterproofed. The latter makes a very sanitary and satisfactory finish if properly made. Insulation should be fastened on to the walls and ceilings very firmly, to prevent bulging and cracking, which would eventually destroy the insulation. All joints should be wrapped or offset in order to prevent air leaks.

## Brine

Brine is a mixture of salt and water. The salt is usually sodium chloride or calcium chloride. The latter is more often used in the ice cream plant because it gives a brine with a lower freezing point. Other mixtures, such as alcohol and water, are used in some installations.

Brine is used, first, because it will store up refrigeration; second, because it will transfer heat at low temperatures from one cold body to another; and third, because it may be used where ammonia leaks would be dangerous.

**Properties of Brine.**—The freezing point of brines is affected by the concentration, that is, by the percentage of salt dissolved in the brine. If the specific gravity is increased certain properties of the brine are a affected. Tables LXXXVIII and LXXXIX, which show the properties of calcium chloride brine and sodium chloride brine, illustrate these points. Practical use is made of this fact; by merely testing the strength of the solution, such properties of the brine as its freezing point and its specific heat may be accurately determined. Different scales of hydrometers are commonly used. The first is the specific-gravity hydrometer. This gives a reading which is a certain percentage of the weight of distilled water per unit volume. The second is the Baumé hydrometer,[2] which has an arbitrary scale. The same tables show the relationship between the various readings. It should be noted that the hydrometer reading is affected by the temperature of the solution as it is tested. As the tables are given for 60° F., either the brine should be brought to this temperature or a suitable correction factor should be made, as shown in the table. Note also that the specific gravity and Baumé readings may be readily converted one to the other by the use of the following formula:

$$\text{Specific gravity} = \frac{145}{145 - \text{Baumé}}$$

[2] Applicable to Baumé scale for liquids heavier than water. The third type of hydrometer is known as the salometer. One scale is used for sodium chloride brine and one for calcium chloride.

Conversely,

$$\text{Degrees Baumé} = 145 - \left(\frac{145}{\text{Sp. gr.}}\right)$$

TABLE LXXXVIII

Calcium Chloride Solution

| Degrees Baumé, 60° F. | Specific Gravity, 60° F. | Degrees Salometer, 60° F. | Per Cent $CaCl_2$ by Weight | Pounds $CaCl_2$ per Gallon of Solution (Approx.) | Freezing Point, °F. | Specific Heat |
|---|---|---|---|---|---|---|
| 0 | 1.000 | 0 | 0 | 0 | +32.0 | 1.00 |
| 1.0 | 1.007 | 4 | 1 | ........ | 31.1 | 0.99 |
| 2.1 | 1.015 | 8 | 2 | ........ | 30.4 | 0.97 |
| 3.4 | 1.024 | 12 | 3 | ½ | 29.5 | 0.96 |
| 4.5 | 1.032 | 16 | 4 | ........ | 28.6 | 0.94 |
| 5.7 | 1.041 | 22 | 5 | ........ | 27.7 | 0.93 |
| 6.8 | 1.049 | 26 | 6 | 1 | 26.6 | 0.91 |
| 8.0 | 1.058 | 32 | 7 | ........ | 25.5 | 0.90 |
| 9.1 | 1.067 | 36 | 8 | ........ | 24.3 | 0.88 |
| 10.2 | 1.076 | 40 | 9 | 1½ | 22.8 | 0.87 |
| 11.4 | 1.085 | 44 | 10 | ........ | 21.3 | 0.86 |
| 12.5 | 1.094 | 48 | 11 | ........ | 19.7 | 0.84 |
| 13.5 | 1.103 | 52 | 12 | 2 | 18.1 | 0.83 |
| 14.6 | 1.112 | 58 | 13 | ........ | 16.3 | 0.82 |
| 15.6 | 1.121 | 62 | 14 | ........ | 14.3 | 0.815 |
| 16.8 | 1.131 | 68 | 15 | 2½ | 12.2 | 0.795 |
| 17.8 | 1.140 | 72 | 16 | ........ | 10.0 | 0.78 |
| 19.0 | 1.151 | 76 | 17 | ........ | 7.5 | 0.77 |
| 20.0 | 1.160 | 80 | 18 | 3 | 4.6 | 0.755 |
| 21.0 | 1.160 | 84 | 19 | ........ | + 1.7 | 0.74 |
| 22.0 | 1.179 | 88 | 20 | ........ | − 1.4 | 0.73 |
| 23.0 | 1.188 | 92 | 21 | 3½ | 4.9 | 0.72 |
| 24.0 | 1.198 | 96 | 22 | ........ | 8.6 | 0.71 |
| 25.0 | 1.208 | 100 | 23 | ........ | 11.6 | 0.70 |
| 26.0 | 1.218 | 104 | 24 | 4 | 17.1 | 0.69 |
| 27.0 | 1.229 | 108 | 25 | ........ | 21.8 | 0.685 |
| 28.0 | 1.239 | 112 | 26 | ........ | 27.0 | 0.68 |
| 29.0 | 1.250 | 116 | 27 | 4½ | 32.6 | 0.67 |
| 30.0 | 1.261 | 120 | 28 | ........ | 39.2 | 0.665 |
| 31.0 | 1.272 | 124 | 29 | ........ | 46.2 | 0.66 |
| 32.0 | 1.283 | 128 | 30 | 5 | −54.4 | 0.65 |

TABLE LXXXIX

Sodium Chloride (Salt) Solution

| Degrees Baumé at 60° F. | Specific Gravity at 39° F. | Degrees Salometer at 60° F. | Pounds of Salt per Gallon of Solution | Pounds of Salt per Cubic Foot | Percentage of Salt by Weight | Freezing Point, °F. | Specific Heat | Weight per Gallon at 39° F. |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.007 | 4 | 0.084 | 0.628 | 1 | 31.8 | 0.992 | 8.40 |
| 2 | 1.015 | 8 | 0.169 | 1.264 | 2 | 29.3 | 0.984 | 8.46 |
| 3 | 1.023 | 12 | 0.256 | 1.914 | 3 | 27.8 | 0.976 | 8.53 |
| 4 | 1.030 | 16 | 0.344 | 3.573 | 4 | 26.6 | 0.968 | 8.59 |
| 5 | 1.037 | 20 | 0.433 | 3.238 | 5 | 25.2 | 0.960 | 8.65 |
| 6 | 1.045 | 24 | 0.523 | 3.912 | 6 | 23.9 | 0.946 | 8.72 |
| 7 | 1.052 | 28 | 0.617 | 4.615 | 7 | 22.5 | 0.932 | 8.78 |
| 8 | 1.061 | 32 | 0.708 | 5.295 | 8 | 21.2 | 0.919 | 8.85 |
| 9 | 1.068 | 36 | 0.802 | 5.998 | 9 | 19.9 | 0.905 | 8.91 |
| 10 | 1.076 | 40 | 0.897 | 6.709 | 10 | 18.7 | 0.892 | 8.97 |
| 12 | 1.091 | 48 | 1.092 | 8.168 | 12 | 16.0 | 0.874 | 9.10 |
| 15 | 1.115 | 60 | 1.389 | 10.389 | 15 | 12.2 | 0.855 | 9.26 |
| 20 | 1.155 | 80 | 1.928 | 14.421 | 20 | 6.1 | 0.829 | 9.64 |
| 24 | 1.187 | 96 | 2.376 | 17.772 | 24 | 1.2 | 0.795 | 9.90 |
| 25 | 1.196 | 100 | 2.488 | 18.610 | 25 | +0.5 | 0.783 | 9.97 |
| 26 | 1.204 | 104 | 2.610 | 19.522 | 26 | −1.1 | 0.771 | 10.04 |

A brine-testing outfit should include a thermometer for measuring the temperature, a hydrometer for measuring the specific gravity, and a graduate or flask for holding the brine. The specific heat of brine, or, in other words, its heat-absorbing capacity per unit weight, decreases with an increase in the concentration. This is a disadvantage which cannot be avoided, and in calculating the heat carried by brine, it should also be considered.

### PROBLEMS SHOWING HEAT CARRIED BY BRINE

**Problem 1.**—Find the heat absorbed in one minute by 200 gals. of calcium chloride brine of a density of 1.218, when the temperature rise is 4° F.

*Solution:* B.T.U. transmitted = weight of brine pumped per minute times specific heat, times temperature rise.

1 gal. of brine of the specific gravity of 1.218 weighs 8.34 times 1.218 = 10.15812 lbs.

The specific heat of calcium chloride brine of the density 1.218 = 0.69.

Therefore, B.T.U. absorbed = $10.15812 \times 0.69 \times 4 \times 200 = 5607.20$.

**Problem 2.**—Find the available refrigeration stored in a 6000-gal. brine tank if the maximum allowable temperature rise of the brine is 10° F. and the density of the brine is 1.218.

*Solution:* Available refrigeration = weight of brine times specific heat times temperature rise.

Available refrigeration

$$= 6000 \times 10.15812 \times 0.69 \times 10 = 420{,}546.168 \text{ B.T.U.}$$

The sodium chloride brine is made from sodium chloride, which is common salt. A saturated solution contains 2.488 lbs. of salt per gallon, and the freezing point of the 25 per cent by weight solution is + 0.5° F. A 29 per cent solution gives a freezing point of − 4.7° F. Sodium chloride brine is less expensive than most other brines and is very commonly used on temperatures that are not lower than 5 or 10° F. It is quite corrosive to certain metals.

Calcium chloride brine is made from calcium chloride, having the chemical formula $CaCl_2$. This salt is produced as a by-product of the manufacture of chlorine and also by other methods. It has a very great affinity for water, and on this account is often used for controlling the humidity of cold-storage rooms. Small pans of the salt set about in the

room will absorb moisture from the air. The salt may be obtained in rock, granulated or flake form. It is always kept in an air-tight container, as otherwise it will absorb moisture from the air and go into solution. The granulated or flaked form is more easily and quickly dissolved, but otherwise has no advantages over the rock form and is slightly higher in price. Calcium chloride often contains impurities, and the best calcium chloride contains approximately 75 per cent calcium chloride and 25 per cent water, by weight. This weight of the water should be allowed in making up brines. Practically all other impurities in the salt are undesirable, as they tend to increase corrosion of the brine lines. The principal impurity found is magnesium. A saturated solution of calcium chloride brine contains 30 per cent salt by weight, has a specific gravity of 1.283, and freezes at − 54° F. The principal advantages of this kind of brine are that it will withstand very low temperatures and may be made practically non-corrosive by certain forms of treatment. It should always be kept away from contact with air in order to prevent absorption of moisture.

Alcohol and water are used in certain types of ice cream cabinets as a brine. A concentration should be kept within the proper limit, just as with any other brine, in order to prevent freezing. Since alcohol evaporates readily, the brine should be tested more frequently than one of the calcium chloride or salt variety. Table XC shows the strength and freezing point of the several solutions of alcohol and water.

TABLE XC *

THE FREEZING POINTS AND SPECIFIC GRAVITIES OF CERTAIN ANTI-FREEZING SOLUTIONS

| Solution | Percentage (by Volume) in Water, and Freezing Points | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 per cent | | 20 per cent | | 30 per cent | | 40 per cent | | 50 per cent | |
| | °C. | °F. | °C. | °F. | °C. | °F. | °C. | °F. | °C. | °F. |
| Denatured Alcohol....... (90% by vol.)......... | −3 | +27 | −7 | +19 | −12 | +10 | −19 | −2 | −28 | −18 |
| | (0.988) | | (0.978) | | (0.968) | | (0.957) | | (0.943) | |
| Wood alcohol........... (97% by vol.)......... | −5 | +23 | −12 | +10 | −19 | −2 | −29 | −20 | −40 | −40 |
| | (0.987) | | (0.975) | | (0.963) | | (0.952) | | (0.937) | |
| Distilled glycerine....... (95% by wt.)......... | −2 | +29 | −6 | +21 | −11 | +12 | −18 | 0 | −26 | −15 |
| | (1.029) | | (1.057) | | (1.085) | | (1.112) | | (1.140) | |
| Ethylene glycol......... (95% by wt.)......... | −3 | +26 | −9 | +16 | −16 | +3 | −24 | −11 | −35 | −31 |
| | (1.016) | | (1.031) | | (1.045) | | (1.058) | | (1.070) | |

* U. S. Bureau of Standards.

In any brine tank, it is necessary to have good agitation in order to get efficient results from the plant. Without it, the heat transfer is very slow. Several different methods are used for producing agitation. The most common method is to use a propelling type of agitator driven by an electric motor. This may be placed in one end of the tank; by means of suitable baffles, a good circulation can be established. Another method is to use a pump which draws the brine out of one side of the tank and puts it in at the other. By proper agitation, the heat conductivity of the coils in the brine tank may be made practically twice as great as it would be with a still brine.

**Corrosion of the Brine Tank.**—In many plants considerable trouble is experienced through corrosion of pipes and tanks connected with the brine system. This may result in the eating away of pipes, the stopping up of pumps, or the corrosion of the coils and tanks themselves. The importance of the problem can be realized when it is considered that many of the large organizations of engineers and chemists are taking this as one of their principal problems. Its importance is also emphasized by the fact that practically no plant is entirely free from its destructive action. The cost of replacement of materials is not the only cost, since the labor involved very often amounts to more than the cost of the materials themselves. A considerable amount of work has been done along this line, and investigators have come to the conclusion that the corrosion is caused by electrolytic action, which is very similar to that which goes on inside of batteries. There are a number of factors favoring this action in the brine tank. If these can be controlled, the corrosion can be very largely prevented. This may be illustrated by placing in an electro-chemical battery two dissimilar metals in a solution which is slightly acid or basic in its reaction. One of the metals will go into solution, with a resulting formation of oxygen and hydrogen. If the brine gives a slight acid reaction or a strong alkaline reaction in a brine tank, for instance, a similar chemical reaction takes place between the various kinds of metal with which the brine is in contact. There is a gradual wasting away of one of them. Though the pitting may extend over a large area, it may, on the other hand, be confined to a small one. There are several ways in which this action can be prevented. First, the brine may be prevented from becoming acid. An acid brine reacts much more readily than a neutral or slightly alkaline one. Second, the brine system may be built by using only one metal, and that as pure as possible. When the first method is used, the acidity of the brine is caused principally by the absorption of air. The brine, therefore, should not be allowed to spray through the air at the time of its return to the tank; furthermore, the top of the

tank should be covered. Air should not be bubbled through the brine in order to produce agitation, as is sometimes done. From the standpoint of corrosion, this is the worst possible thing that could be done. Acidity may be detected by the use of litmus paper, which will turn red if the brine is acid; or phenolphthalein solution, which will remain colorless if the brine is acid but will turn pink if it is alkaline. The acidity or alkalinity of the brine is often expressed as a $p$H constant. A brine having a $p$H 7 is neutral, while one having a $p$H 6 or 5 is acid, and one having a $p$H 8 or 9 is alkaline. The curve in Fig. 88 shows the relative rates of corrosion of brine with respect to the $p$H constant. From this curve, it is evident that for best results the $p$H should be kept as near 7 as possible. This means, of course, that the brine should be nearly neutral or slightly alkaline. Brine should be tested every few weeks and, if found acid, should be corrected by the addition of a small amount of lime water or a weak solution of sodium hydroxide or caustic soda. If lime is added to the brine, it should be well mixed in the form of a thick liquid or slurry, and should be poured into the tank at a point where the agitation is good. If lime is poured into the tank in powdered form it has a tendency to settle to the bottom and form a deep sludge; if added by means of a bag hung in the brine, the bag will become coated over with crystals, thus preventing the lime from going into solution. Figure 89 shows the effect of the density upon the oxygen-absorbing capacity of brine, which in turn regulates to a large degree the acidity. It is apparent that the rate of corrosion can be very materially decreased by maintaining the brine at high density. It may be further mentioned that, from a number of brine systems which have been studied, the open brine systems were found to be 80 per cent oxygen-saturated, while the closed were only 20 per cent saturated, thus demonstrating the advantage of using the latter.

From a study of the effect of the metals out of which the brine system is constructed, investigators have found that a pure grade of cast iron is quite resistant to corrosion. Ordinary steel fittings are very quickly attacked, and zinc is also readily dissolved by brines. There is an advantage in using zinc, however, especially in connection with salt brines, for it will go into solution more easily than iron, and thus as long as there is zinc available, the iron will not be eaten away. Use is sometimes made of this property by attaching a bar of zinc to the metal of the tank. Tin has exactly the opposite effect. Since the iron will go into solution more quickly than tin, tinned iron is not as good as galvanized for use in contact with brine.

**Iceless Cabinets.**—The iceless cabinet has lately come into extensive use for holding ice cream at low temperatures. It is nothing more than

a small, complete refrigeration plant connected to an insulated brine tank which surrounds the ice cream compartments. The cabinets are

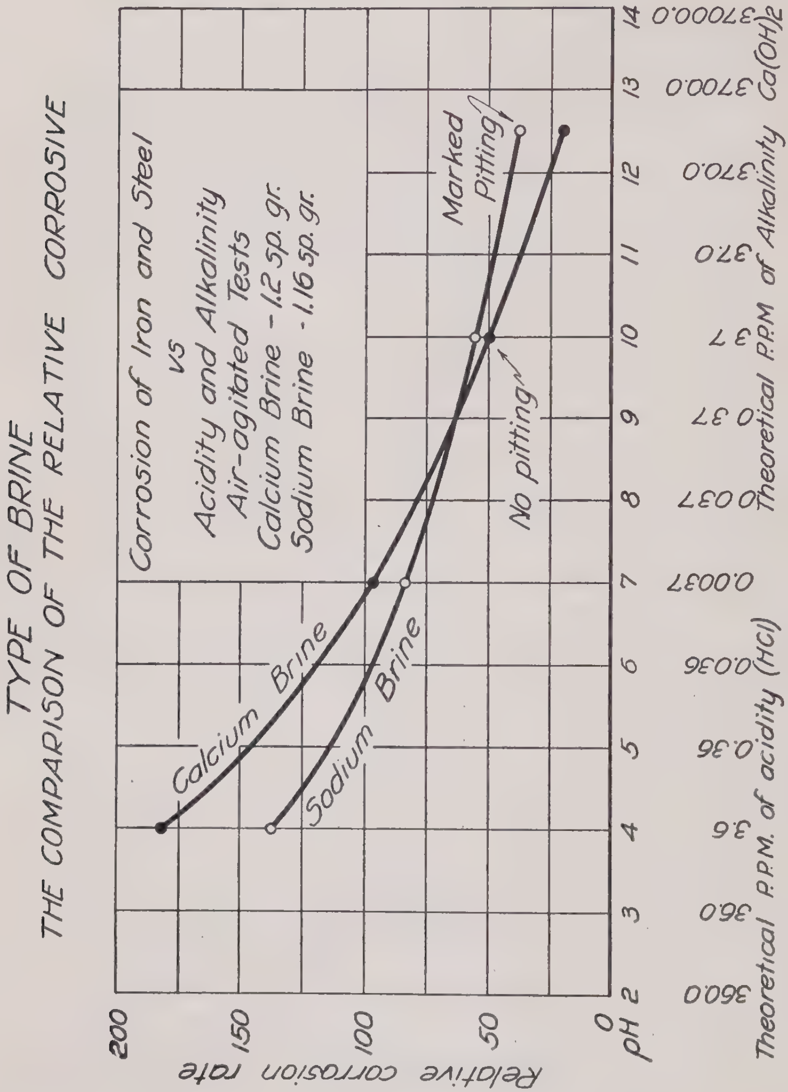



Fig. 88.

made in sizes from 2-hole capacity up to 10 or 12; and in some cases have been built to maintain more than one temperature. The machines are entirely automatic in operation and are driven by an electric motor

which is started and stopped by thermostat switches to maintain a practically uniform temperature is maintained. The compression type of refrigeration machine is used almost exclusively; the refrigeration may be ammonia, sulphur dioxide, methyl chloride, or some similar material. Sulphur dioxide and methyl chloride are most commonly used at this time. These refrigerants have the advantage of a low condensing pressure. The brine tank is usually of seamless sheet iron or copper, surrounded by 2 to 4 inches of cork board set in hyrolene or asphalt waterproof material. Since sulphur dioxide gas forms a corro-

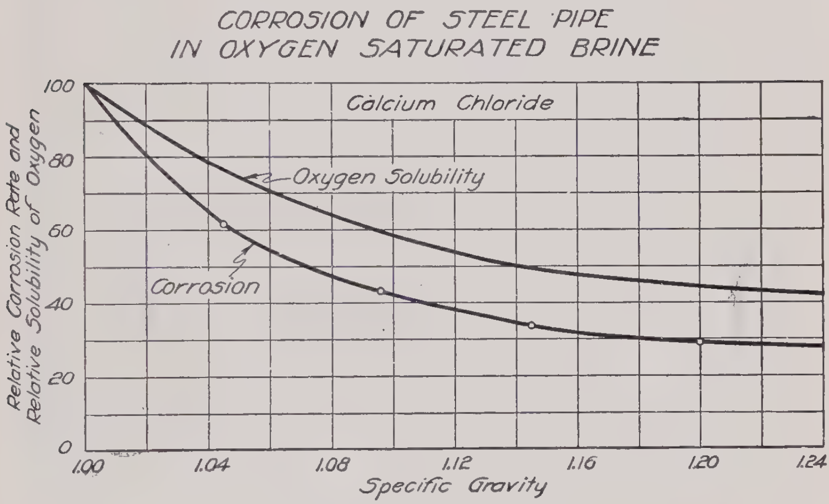
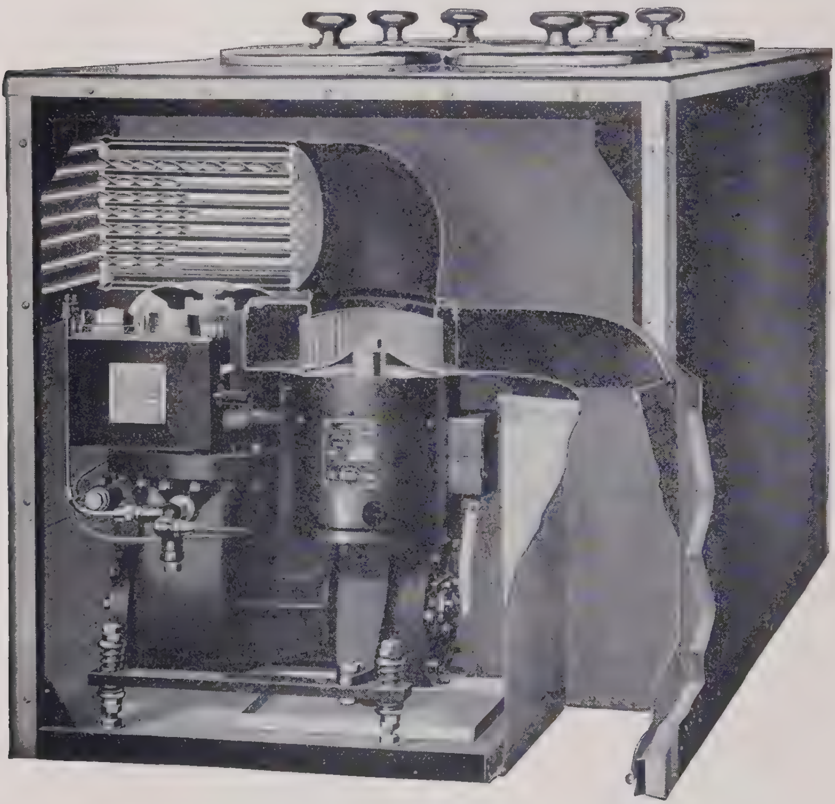



FIG. 89.

sive acid in the presence of moisture, care should be taken to prevent its entrance into the system.

The expansion coil differs somewhat from that in the large refrigeration machine in that it is more in the form of a "water-tube" boiler, which is submerged in the brine tank. It operates upon the flooded principle, which means that the tubes are at all times filled with the refrigerant, and that the level of refrigerant in the boiler is automatically maintained by a suitable float valve or by an expansion valve. The float valve is the most popular type. Figures 90, 91 and 92 show the detail of construction of a typical iceless cabinet. The refrigerant used in an icelesss cabinet may be condensed by cooling with water or with air. The air-cooled machine is somewhat simpler in construction, has fewer parts to get out of order, has less up-keep expense, and is more easily moved from place to place than the water-cooled machine. For these

reasons it is the most popular in places where the air temperature does not reach much over 100° F., and it has been successfully used even in the warmest localities, such as the Imperial Valley in California. The electrical energy consumed is slightly greater than in a water-cooled outfit, but this is more than overbalanced in most circumstances by the other factors. The water-cooled cabinet must have an automatic water-regulating valve, which is turned on and off when the machine starts

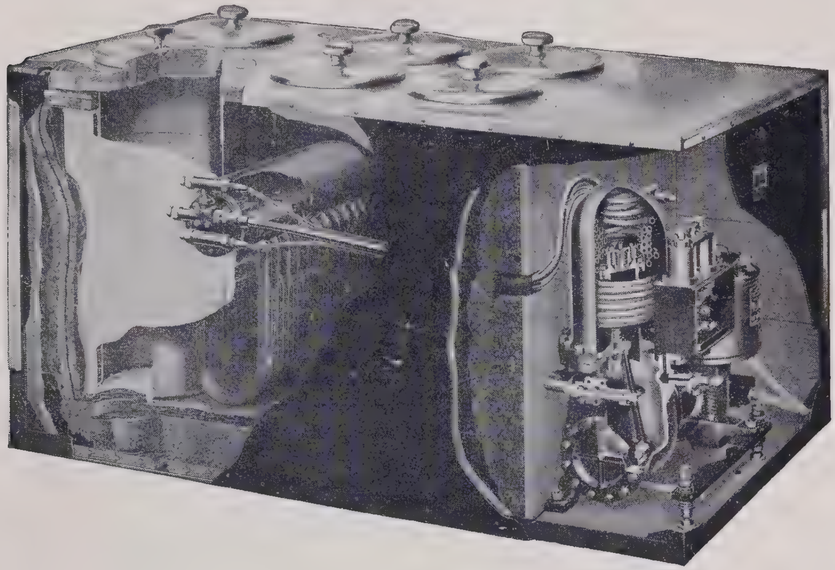


*Courtesy Nizer Corporation*

FIG. 90.—Cutaway of Air-cooled Self-contained Cabinet.

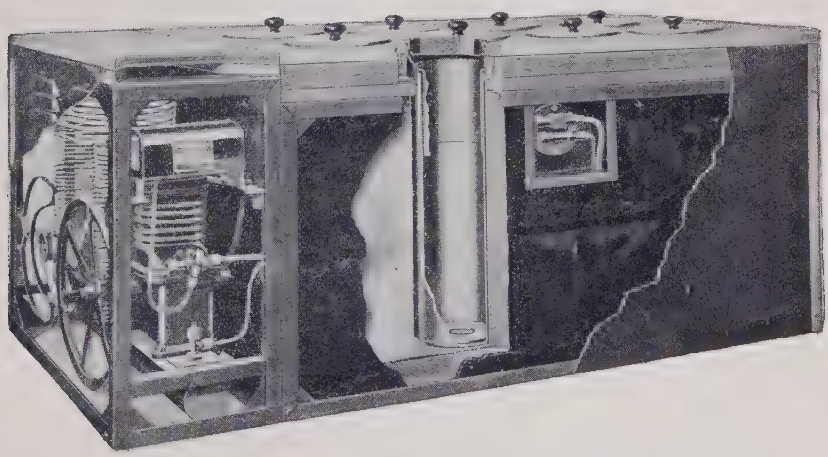
and stops, and must be supplied with connections to a water line. If the water pressure should go off, a high pressure will be built up in the machine, and it will either stop or cause trouble by blowing out gaskets or bursting a pipe. Special controls are always installed on the machine to turn off the power under these conditions; very little trouble has been experienced in so far as damage to the machine is concerned.

The cost of operation of a 4-hole cabinet, water-cooled type, is not excessive. Tests conducted at the University of California showed an



*Courtesy Nizer Corporation*

FIG. 91.—Cutaway of a Water-cooled Self-contained Cabinet.



*Courtesy Frigidaire Corporation*

FIG. 92.—Cutaway of Air-cooled Iceless Cabinet.

average power consumption of 2.6 kilowatt-hours per twenty-four-hours. The air-cooled type is practically the same.

## POWER

In selecting the type of power for use in an ice cream plant, the following points should be considered: first, cost of operation; second, reliability; third, effect on sanitation; and fourth, flexibility.

From the standpoint of cost, if large steam boilers are used for heating and processing, the power can be generated as a by-product of the heating, since practically all of the heat which enters a steam engine is carried out in the exhaust steam and may be used for other purposes after it has given up its power. Gas engines may be used in many places where sufficient steam is not available. The heavy-oil Diesel type of engine is very economical to operate, and with proper care should last for many years. Electrical power may also be used. In many places it is more economical to purchase the electrical energy directly from power companies than to generate it at the factory. Even though steam or gas engines are used for power, it will most often be desirable, especially with a plant of large size, to transform the power into electrical energy and use and electric motor drive for the individual machines. Since steam and gas engines would require so much space to cover all details, the reader is advised to consult the references given at the end of this chapter for further information regarding their use. Electric motors, however, are so commonly used, and their care and operation is so simple, that some space will be given to them.

**Selection of Electric Motors.**—The three-phase, squirrel-cage type of electric motor is perhaps the most satisfactory one for general purposes in ice cream plants. It is extremely simple, has only one moving part, and is easily protected from moisture by a ventilated cover. Three-phase motors have high efficiency and good starting power. They must be operated on three-phase circuits. Single-phase motors are more expensive, are not quite so efficient, and are more difficult to protect from moisture, since they employ brushes and a commutator or a contactor. Their principal advantage is that they can be used on single-phase lines. Practically all power lines to-day are three-phase. The single-phase motor is often used in the small fractional horse-power sizes on account of the simplicity of its wiring. A very satisfactory motor of this type is the repulsion-induction motor, which has very good starting power and is efficient.

The synchronous motor is a special type of motor which can raise the power factor of the system; it has very high efficiency. Synchronous motors are used in sizes of 50 horse-power and larger, and are becoming quite popular for driving refrigeration machines directly connected.[3]

[3] The power factor is the percentage given by dividing the true power carried by an electric line by the apparent power. It is found by dividing the watts, as measured

Whatever the motor selected for use in an ice cream plant, it must be first of all, of the proper size: that is, it must handle the load under all normal conditions and must have sufficient starting torque to bring the load up to full speed.

The second consideration should be that of ruggedness and reliability. The motor should be of as simple construction as possible and have great reliability and strength. In the third place, it should be able to resist the high moisture conditions under which it must work, and fourth, the reliability of the manufacturer must be taken into consideration. Repairs and service should be available within a reasonable distance. It is well to make use of the manufacturer's services for any special problem which may present itself.

**Care of Motors.**—Lubrication of bearings is most important. Perhaps 90 per cent of motor troubles can be traced to failure of the bearings, which is nearly always due to lack of proper lubrication. A periodic or weekly inspection of all bearings, therefore, is essential. The manufacturer's directions should be followed explicitly, particularly regarding the proper type of oil to use. A medium-bodied or light mineral oil is recommended for general use with electric motors. Hardly less important than lubrication is the care of connections to the motor. A loose connection not only causes lack of power but may cause the motor to burn out by throwing all of the load on one set of wires. All connections should be soldered or bolted together securely with lugs, and then taped, first with rubber tape and then with friction tape. All exposed wiring should be carried in conduit to protect it from mechanical injury and from being splashed with water. The rigid conduit is better than the flexible, because it is more nearly waterproof.

A third consideration should be the protection of the motor from moisture. The greatest enemy of electricity is moisture, and since there is so much of it about an ice cream plant, special precautions must be taken to prevent trouble, as it frequently causes shorts and grounds. It is practically impossible to build the ordinary motor in such a way that it is entirely waterproof, although the three-phase motor will withstand considerable moisture. It is advisable to use hoods or shields over all electrical equipment. A good type of hood is shown in Fig. 93. This shield allows ventilation, which is very important in keeping the

by a wattmeter, by the product of volts times amperes. This applies only to alternating-current lines and is of importance, since lines operating at low power factor must carry a larger current, in order to transmit a given amount of power, than would a line which has unity power factor.

$$\left(\frac{\text{Watts}}{\text{Volts} \times \text{Amperes}} = \text{Power Factor}\right)$$

motor cool and dry. Some motors are built with specially protected windings enclosed in a waterproof substance. These have given good service under actual commercial conditions. Completely enclosed motors are sometimes used, but trouble is frequently experienced from overheating. Motors may be located on a raised block or on the wall where they are not apt to come in contact with water. It is never a good policy to set a motor directly on a floor that sometimes has water on it. Motors that have become water-soaked and grounded should be dried out by baking in an oven for twelve hours at a temperature of 150° F.; or, if the motor is too large to move, it may be dried out by passing an electric current through the windings while the rotor blocked. It is very important to control accurately the amount of current going through the windings, as there is great danger of running too much current through the motor and burning it up. It is a good policy to dry out motors thoroughly once every year and to spray them with a good insulating and waterproof paint, being particularly carful to cover the windings.

Fig. 93.—A Simple Type of Ventilated Motor Hood Prevents Moisture from Injuring Motors.

**Loading of Motors.**—The proper loading of motors is one of the greatest factors in their economical and successful use. Overloading is expensive and dangerous because of the possibility of burn-outs, while underloading is expensive because of the greater first cost of equipment and because of lower efficiency in operation. A loss in efficiency of from 4 to 8 per cent is found in many motors when the load is reduced from full to half. The average motor has the ability to carry momentary overloads of 50 per cent without injury. The limit of load is really determined by the heating of the motor. In a system in which there is a low power factor or low voltage, a motor will not carry as great a load as under normal conditions. It is the average load and not the peak load which determines the size of motor to be used, that is, provided there is no momentary overload sufficient to stall the motor. In all cases where there is doubt, it is advisable to check up the actual requirements of a machine before determining the size of motor to buy. It is always better to use a motor that is too large than one that is too small.

The University of California has conducted an investigation covering a large number of ice cream freezers and found that the average power consumption for freezers of 40-qt. brine type was 2.12 horse-power when

freezing under regular commercial conditions. There was a considerable difference, however, in the power consumption of different types of machines. Table XCI shows the power consumption of two different types of machines of the same capacity. The vertical machine used a high-speed, squirrel-cage type of dasher, a fact which accounted for the high power consumption. The point to be considered is that there is a difference in the power consumption of various types of machines and that no one size of motor will be most efficient for all different types. The investigation showed that the energy consumed by each batch of ice cream frozen varied from .522 to .279 kilowatt-hours, depending upon the type of machine.

TABLE XCI

VARIATION IN POWER REQUIREMENTS OF FREEZERS AS CAUSED BY VARIATION OF SPEED AND TYPE OF DASHER

| Type of Freezer | Speed of Dasher R.P.M. | Minutes to Freeze | Average H.P. | Maximum H.P. |
|---|---|---|---|---|
| Vertical (Squirrel Cage Beater) | 225 | 12′ 48″ | 3.30 | 4.69 |
| Horizontal (Paddle Dasher with Blades) | 165 | 12′ 18″ | 1.83 | 2.66 |

**Electrical Accessories.**—There are certain electrical accessories which must be used in the ice cream plant and which must be properly selected. A switch or starting box is required with every motor. Switch boxes are used with most motors below $7\frac{1}{2}$ horse-power, while starting boxes which reduce the voltage at the time of starting a e used with those above $7\frac{1}{2}$ horse-power. The switch should be safe, easily operated, and large enough to carry the current needed by the motor. It should break the circuit quickly and with a minimum of sparking; otherwise trouble will be had from burning contact points. Totally enclosed switches should be used, as they are more nearly waterproof and protect the operator. Some switches are turned on and off by hand-operated levers, while others are operated merely by pushing a button. The latter type is preferable, because the starting and stopping button may be placed on the machine near where the operator stands, and thus save time. The switch itself may be placed high up on the wall out of the reach of moisture. Safety switches are those that cannot be opened while the power is turned on and cannot be turned on while they are open, thus eliminating the danger of shocks to the operator.

**Selection of Fuses.**—The proper fusing of electric lines is of great importance, for it is to the electric line what the safety plug is to the steam boiler. A fuse contains a small strip of metal which melts out when a current greater than a predetermined amount is passed through it. This breaks the circuit and stops the flow of electricity. The practice of placing pennies, wires, or nails in fuses so that they will not burn out is dangerous and might be compared to the practice of placing a steel plug in the place of the safety plug on a boiler. The result may be a burned-out motor, a burned-out line, burned-out wires, or possibly a fire. Figure 94 shows four types of fuses commonly used on motor and light circuits.

No. 1 is the plain plug type of fuse which is used mostly in light circuits and is made in small sizes. No. 2 is the plain cartridge type, such as is used on lighting and motor circuits in size from 3 amperes up to 400 or more. No. 3 is a time-limit fuse, which is used very largely


FIG. 94.—Different Types of Fuses are Available for Various Purposes.

on motor circuits. The last has the advantage that it will not burn out on a momentary overload like the ordinary fuse, yet if the overload continues for a considerable time, it will burn out and protect the motor. No. 4 is a removable link fuse.

The size of fuse selected should be such that it will carry no more than the maximum safe carrying capacity of the circuit on which it is to be used. Fuses are rated according to the number of amperes of current they will carry and are not affected by changes in voltage, within certain limits. For instance, those which can be used on 110 volts can ordinarily be used on a 220-volt line. Those of higher voltage are usually of somewhat different construction. Fuses for motors should be selected with special reference to the type of load and motor with which they are to be used. This is because motors draw a heavy starting current for only a short time, which would burn out a plain fuse small enough to afford protection against a continuous running overload. Many times, if plain fuses are used, one set will be installed to care for the starting load and another for the running load. The "starting" fuses should be rated at approximately 200 per cent of the name plate amperage of the motor

with which they are to be used, while the "running" fuses should be of 115 to 125 per cent of the name plate amperage. Time-limit fuses will usually be of either the same as or 110 per cent of the name plate amperage of the motor. They are much superior to the plain fuses, since they carry an overload for a certain length of time without "burning out" and will thus care for the starting load and at the same time give running protection.

With large motors and on certain types of equipment, overload relays take the place of fuses and open the circuit in case of overload. These are of two general types. The thermal overload relay opens the circuit by means of a small blade which is bent to one side when heated by the current to a certain predetermined temperature. The magnetic overload relay opens the circuit by the action of a plunger, which is raised by the pull of the magnet when a predetermined current value is exceeded. Relays can be easily adjusted to operate at the proper point.

**Lighting for the Ice Cream Plant.**—Sufficient light is necessary in the ice cream plant in order to make efficient use of labor, to make possible better health of workers, and to provide more sanitary conditions. The proper intensity of lighting for dairy plants, as recommended by illuminating engineers, has been set at a value of 4 to 8 foot candles. A simpler method of arriving at approximately this value is to allow approximately $1\frac{3}{4}$ watts' lamp capacity per square foot of floor area. Light-colored walls will greatly increase the efficiency of lighting and are found in a large percentage of ice cream plants. The selection and placing of fixtures is of considerable importance, and the services of an illumination expert should be obtained in this connection. In general, for factory conditions, the porcelain enameled type of reflector has been found very good, as it has high powers of reflection, is not easily broken, is cleaned without difficulty, and is inexpensive. Electric lamps of the proper voltage should be selected, since those under voltage will have a short life while those of higher voltage will be inefficient. The normal life of an electric-light bulb is 1000 hours; it should be replaced at this time if the best lighting efficiency is desired. The pilot light is a very desirable signal for use in connection with cold-storage rooms and other places where a tell-tale light is needed for indicating to the operator that certain electric circuits are on.

**Heating with Electricity.**—Electrical energy has been used successfully for heating where it is not expensive. It saves considerable labor and offers better control of temperatures than other methods. It has certain advantages of cleanliness which are important in laboratory use and in some forms of process work. Electric heating units are 100 per cent efficient, and if proper insulation is used with them, a higher

over-all efficiency can be obtained than when using coal or oil. One kilowatt-hour will produce 3415 B.T.U.

### PUMPING

An ice cream plant uses many pumps and often a number of different types. Each of the three principal types of pumps has certain advantages. The plunger or piston type pump is quite simple in construction, is positive in action, and has a fair efficiency. A positive pump, if the discharge valve is closed, will build up pressure to the bursting point or until the belt slips, if it is belt-driven. It has the disadvantage of requiring valves and a stuffing box. These make it more difficult to keep in repair than some other types. It also gives a pulsating pressure if operated slowly. The second type of pump is a rotary displacement pump, in which the teeth of a special type of gear act as small pistons and thereby do the pumping. The Viking pump is a good example of this type. This pump has the advantage of delivering a steady non-pulsating pressure and may be directly connected without difficulty. A rotary pump requires only one stuffing box, has no valves, and is also a positive type. It is apt to become noisy and inefficient, however, after it becomes worn. There are other types of rotary pumps which employ blades and rotary valves instead of gears. The third type depends upon centrifugal force for its action and is known as a centrifugal pump. It is primarily a high-speed pump and is usually connected directly to the motor shaft. The advantages of the centrifugal pump are that it is very quiet in operation, it gives a non-pulsating pressure, it may be connected directly to motors, and its original cost is low compared to that of other types. Furthermore, on brine lines, for example, the discharge valve may be closed without danger of breaking the pump or pipe lines. However, if the valve is allowed to remain closed for any length of time, the packing may heat and be burned out. The disadvantages of this type of pump are, first, that it is not efficient under variable heads, unless its speed can be changed; second, that it must be primed each time before starting, if it is situated above the liquid which it is to pump; third, that it will not pump against high pressure unless it is of multi-stage construction. The efficiency of centrifugal pumps varies from 35 per cent for small, low-capacity pumps, to 75 or 80 per cent for large units. The capacity of the centrifugal pump is affected by the speed of the pump and the head against which it is pumping. Manufacturers usually rate their pumps from the size of the discharge opening, using a velocity of 10 feet per second for the rate of flow of water. Thus, to find the capacity of a pump having a discharge pipe whose area is 2 square inches,

the volume pumped per minute would be $2 \times 10 \times 12 \times 60$ divided by 231. A simpler formula for computing the capacity of a centrifugal pump is: Gallons per minute equals $98 \times R^2$, where $R$ equals the radius of the discharge opening in inches.

**Power Requirements of Pumps.**—The power required for pumping depends primarily upon two factors, the weight of liquid to be pumped and the height to which it must be raised from the source of supply to the point of delivery. In addition, there is required power to overcome mechanical losses in the pump, friction in the pipe lines, and the velocity head needed to give the water motion, since it takes a certain amount of energy to give motion to a body starting from rest.

The theoretical or water horse-power required is given by the formula:

$$\text{H.P.} = \frac{\text{Wt. of liquid per min. in lbs.} \times \text{Height pumped in ft.}}{33{,}000}$$

Since this formula does not take into consideration any of the losses, a different formula is necessary for calculating the actual power necessary.

$$H.P. = \frac{W \times H}{33{,}000 \times E}$$

$W$ = Wt. of liquid pumped per min.

$H$ = Total head in feet

$E$ = Efficiency of the pump.

In the formula above, $H$ and $E$ are different from the first formula. $E$, being the efficiency of the pump, will vary from 0.35 to 0.80 with an average value of perhaps 0.50. (Note that the efficiency is expressed as a decimal.) $H$, or the total head, is made up of the following:

(*a*) Lift head, or height the water is raised above the center of the pump.

(*b*) Suction head, or height water is lifted from below the center of the pump.

(*c*) Velocity head, which is the energy required to give the water its momentum—changed to read in feed head ordinarily neglected in small systems.

(*d*) Friction head, which is the resistance of the pipe, fittings, valves, etc., changed to read in feet head. In other words, the resistance of 100 ft. of 1-in. pipe to the flow of 10 gals. per minute (G.P.M.) of water is the same as if the water were raised 8.4 ft., and, therefore, this much must be added to the total head against which the water is pumped.

## TABLE XCII

### Resistance of Smooth Iron Pipe *

Feet Head per 100 Ft. Length.

| G.P.M. | ¾ | 1 | 1¼ | 1½ | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| 5 | 7.6 | 1.9 | .71 | .27 | .09 | .01 | |
| 10 | 29.9 | 7.3 | 1.4 | 1.00 | .28 | .05 | |
| 15 | 66.0 | 16.1 | 5.5 | 2.2 | .57 | .09 | .02 |
| 20 | 115 | 28.0 | 9.5 | 4.8 | .96 | .13 | .03 |
| 25 | 179 | 43.7 | 14.7 | 6.0 | 1.7 | .23 | .05 |
| 30 | 264 | 63.2 | 21.0 | 8.6 | 2.1 | .30 | .07 |
| 35 | 372 | 85.1 | 28.9 | 11.6 | 2.7 | .39 | .11 |
| 40 | 461 | 110 | 32.0 | 14.9 | 3.7 | .53 | .14 |
| 50 | ....... | 185 | 57.3 | 23.0 | 5.6 | .80 | .20 |
| 60 | ....... | 253 | 82.8 | 32.2 | 8.0 | 1.2 | .30 |
| 70 | ....... | 340 | 116 | 46.0 | 11.0 | 1.4 | .44 |
| 80 | ....... | ....... | 147 | 57.5 | 14.5 | 2.0 | .53 |
| 90 | ....... | ....... | 184 | 73.6 | 17.9 | 2.5 | .60 |
| 100 | ....... | ....... | 228 | 89.7 | 21.7 | 2.9 | .74 |

When pipe is rough add 15 per cent.

* Crane Co.

## TABLE XCIII

### Resistance of Elbows (90°), Feet Head *

| G.P.M. | ¾ | 1 | 1¼ | 1½ | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| 5 | .161 | .062 | .0184 | .0115 | .0046 | | |
| 10 | .644 | .216 | .0713 | .0414 | .0138 | | |
| 15 | 1.449 | .487 | .1587 | .092 | .0322 | | |
| 20 | 2.576 | .864 | .2829 | .1587 | .0575 | | |
| 25 | 4.002 | 1.345 | .4462 | .2484 | .0874 | | |
| 30 | ....... | 1.943 | .6394 | .3611 | .1265 | .0243 | |
| 35 | ....... | 2.645 | .8740 | .4935 | .1748 | .0345 | |
| 40 | ....... | 3.450 | 1.138 | .6394 | .2254 | .046 | .0161 |
| 50 | ....... | ....... | 1.771 | .989 | .3419 | .0736 | .023 |
| 60 | ....... | ....... | 2.553 | 1.426 | .506 | .1012 | .0345 |
| 70 | ....... | 10.58 | 3.49 | 1.978 | .6992 | .138 | .0483 |
| 80 | ....... | ....... | 4.55 | 2.553 | .9016 | .184 | .0621 |
| 90 | ....... | 17.48 | 5.75 | 3.24 | 1.150 | .239 | .0805 |
| 100 | ....... | ....... | 7.084 | 3.95 | 1.40 | .294 | .0989 |

Weight of water per gallon, 8.33 lbs. Weight of water per cubic foot, 62.4 lbs.

* Crane Co.

TABLE XCIV

Conversion of Pounds Pressure to Equivalent Feet Head

| Pounds per Square Inch | Feet Head | Pounds per Square Inch | Feet Head |
|---|---|---|---|
| 1 | 2.31 | 50 | 115.47 |
| 5 | 11.55 | 60 | 138.57 |
| 10 | 23.19 | 70 | 161.66 |
| 15 | 34.64 | 80 | 184.76 |
| 20 | 46.19 | 90 | 207.85 |
| 30 | 69.28 | 100 | 230.95 |
| 40 | 92.38 | | |

TABLE XCV

Conversion of Inches of Vacuum to Feet Head

| Vacuum, Inches | Feet Head | Vacuum, Inches | Feet Head |
|---|---|---|---|
| 1 | 1.13 | 14 | 15.82 |
| 2 | 2.26 | 16 | 18.08 |
| 4 | 4.52 | 18 | 20.34 |
| 6 | 6.78 | 20 | 22.60 |
| 8 | 9.04 | 22 | 24.86 |
| 10 | 11.30 | 26 | 29.38 |
| 12 | 13.55 | 30 | 33.9 |

**Vacuum Pumps.**—Vacuum pumps are merely exhaust pumps, which are used for pumping the air or a mixture of air and water from a container. A very common use is in connection with the condensing pan and with the vacuum system of pumping. Vacuum pumps are of two general types, the dry and the wet vacuum types. The dry vacuum pump is used for pumping only dry gases or air, and is made with very light-weight valves and very small clearances. The wet vacuum pump is built with larger clearances and of heavier valves, and is thereby enabled to handle a considerable amount of water or liquid along with the gases. The commercial type of vacuum pumps for producing high vacuum are usually of the reciprocating piston type and may be driven by a steam cylinder directly connected or by means of a flywheel and crank. Very high vacuum is obtained best by the use of the jet pump, which has the further advantage of economy of space and simplicity of parts. It may

not be so efficient, however, as the piston-type pumps, especially in small sizes.

Vacuum has been successfully used in some plants for drawing mix from one tank to another. For instance, if a Tank *A* is situated above a Tank *B*, the liquid in Tank *B* may be drawn or forced from the ground up into Tank *A* against the force of gravity by creating a suitable vacuum in Tank *A*. There is a practical limit to the height to which this will work, since a perfect vacuum will lift water only about 33.9 ft. at sea level. A vacuum is measured by the height of the mercury column that it will support. A perfect vacuum will support 29.9 ins. of mercury at sea level and would support a column of water 33.9 ft. high. Thus it will be seen that the theoretical limit to the height would be slightly less than 34 ft. The practical limit is about 30 ft. If a liquid other than water were to be raised, the specific gravity would need to be considered. Thus, while a 20-in. vacuum will support a 22.6-ft. column of water, it will support a column of brine, of the density of 1.2, only 22.6 divided by 1.2, or 18.8 ft. The use of vacuum for pumping liquids from one container to another has the advantage of causing practically no agitation to the liquid and eliminates possible sources of contamination. On the other hand, the disadvantages are that air leaks into the system will reduce the efficiency considerably, and that the limit of height to which the liquid can be raised is rather low.

**Brine Pumps.**—The pumping of brine presents the same problem as the pumping of water, except that provision must be made to prevent corrosion. Also, the fact must be considered that brine is heavier than water and, therefore, more power will be required for pumping a certain number of gallons of brine a certain distance than would be required for pumping water under the same conditions. Bronze pumps are very good from the standpoint of corrosion but, because of the expense, have been largely replaced by high-purity cast-iron construction.

**Sanitary Pumps.**—Sanitary pumps are also affected by the same general considerations as water pumps. A principal point of difference is that a sanitary pump is made of bronze, which is not readily attacked by the liquids handled and can be easily cleaned. It is made in such a manner that it may be entirely taken apart for cleaning—a very important consideration. Agitation during pumping is another factor that should receive attention. A slow-moving piston type of pump is desirable from this standpoint, although certain of the well-designed, closed-runner types of centrifugal pumps are used successfully and because of their simplicity have certain advantages over the piston-type pump.

**Transfer of Liquids by Pressure System.**—There are places in which the use of pressure in a tank instead of vacuum might be used for trans-

ferring liquids from one tank to another. Referring to the example cited in the use of the vacuum system, if sufficient pressure had been

*Courtesy Creamery Package Mfg. Co.*

FIG. 95.—Dissembled Pump.

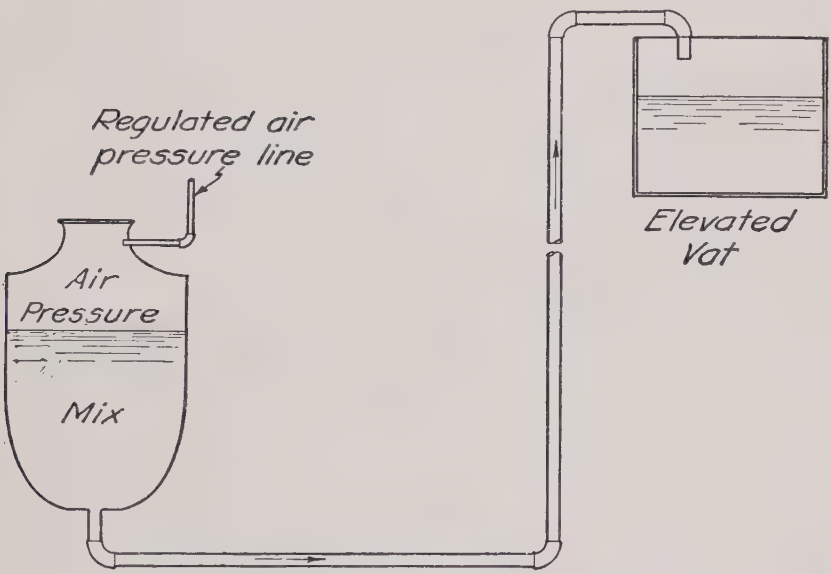



FIG. 96.—Properly Filtered Air Can Be Used to Transfer Mix with the Elimination of Pumps and Their Losses Attendant.

applied to Tank *B*, the liquid could have been forced up into Tank *A* by this means instead of by vacuum as in the previous case. (Vacuum, after all, is merely the removal of the pressure on one side, thus allowing

the pressure of the air to do the pumping.) In the use of the pressure system of transferring liquids, Tank *B*, for instance, must be made strong enough to withstand the pressure necessary and must be made perfectly tight in order to operate efficiently. The pressure system, unlike the vacuum, is not limited, since by increasing the pressure any reasonable height may be obtained. One of the disadvantages, however, of the pressure system is that there is danger of contamination resulting from the air which is pumped into the pressure tank, for this air is very likely to pick up particles of oil as it goes through the pressure pump. It would be necessary, then, to include in the pressure system an oil trap and a pressure reservoir, which would be placed in the pressure line ahead of the tank which holds the liquid to be pumped.

**The Homogenizer.**—The homogenizer is a special type of high-pressure pump. It is usually constructed in sets of three pistons and cylinders operating at 120° from each other in order to give a more uniform pressure. It is usually made single-acting, the three separate cylinders each having a suction and a discharge valve. The discharge from the three cylinders is into a common manifold which then leads to the homogenizing head. The pressures carried vary from 1000 to 4000 lbs. per square inch with an average working pressure of 2500 lbs. per square inch. On account of the high pressures, it is very important that the pistons be accurately fitted and well packed. The packing should be kept soft and pliable and should be renewed at intervals of at least every month or two, not only from the standpoint of wear, but of sanitation. Pistons that have worn over 1 or 2 thousandths of an inch should be replaced. Valves are usually of the pocket type, very similar to those used in ordinary practice, and may be ground in the same manner, using a common valve-grinding compound. Fine emery dust mixed with oil may be used, but is not as convenient as the prepared article. Only 3 or 4 lbs. pressure should be applied to the valve in grinding it, and it should be rotated back and forth a quarter to a half turn each time and then raised and turned a half turn and ground back and forth again until properly fitted. A light spring underneath the valve assists in raising it from its seat, when it is to be turned. It should be finished by wiping off with a piece of cloth and removing all traces of valve-grinding compound with washing solution. Then it should be given a few finishing turns with pure oil or tallow to make a smooth fit. The fit can be tested by making a number of marks on the valve seat and valve with a pencil, and then applying slight pressure to the valve, by turning it through a quarter turn. If the marks are undisturbed at any certain part of the valve, grinding should be continued until a perfect fit is obtained. Care should be taken never to turn the valve one complete

revolution while it is resting against the seat, as scratches may be made, which will cause leakage.

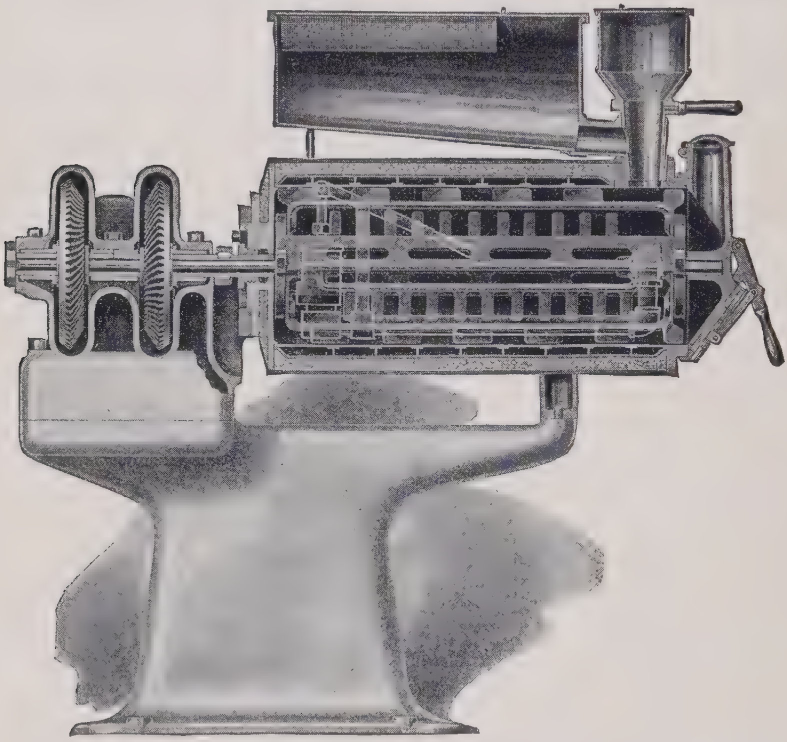
After leaving the discharge manifold of the homogenizer, the mix is passed through an opening to the homogenizing head, which consists of a hardened metal seat, against which a block of hardened metal or composition material is held by a spring. The pressure at which the machine operates is then regulated by the tension of the spring on this homogenizing block. The mix is forced out between the homogenizing block and the seat, it is thus homogenized. This causes a constant wearing away of the seat as well as the homogenizing block and makes necessary regrinding at frequent intervals. The regrinding is accomplished in exactly the same manner as used in the grinding of auto engine valves, the same principles and the same materials being employed. A small amount of grinding every week or at frequent intervals is to be recommended.

Leaky valves and poorly fitting homogenizing heads are indicated by a vibration of the pressure gauge needle or by the needle of an indicating wattmeter or ammeter in the motor circuit.

**The Ice Cream Freezer.**—The ice cream freezer is one of the most important parts of the ice cream plant, for it is here that the mix receives its first stage of the freezing process and the air is incorporated. Freezers that are not functioning properly greatly increase the cost of production and even affect the quality of the ice cream. Figure 97 shows a horizontal-brine type freezer. The freezer consists of a barrel or cylindrical chamber into which a rotating dasher is placed. The cylinder is surrounded by a jacket which may be cooled either by passing brine through it, in the case of the brine-type freezer, or ammonia, in the case of the direct-expansion freezer. There is also a hopper for pouring the mix into the machine and a gate valve for drawing the frozen mix out. An electric motor is usually employed to drive the dasher through a shaft and set of gears. Many of the present-day machines are driven directly by a motor, placed directly on the frame of the machine. The freezer then has two functions to perform. The first is that of extracting part of the heat from the mix so that it comes out in a partially frozen state ready to go to the hardening room. The second is that it must incorporate a certain definitive amount of air into the unit volume of mix.

There are several methods of freezing, but perhaps the one most common is that of freezing the ice cream to a certain stiffness and then turning off the freezing medium and whipping the mix until it has absorbed the required amount of air. From the standpoint of the quality of ice cream, economy of power consumption, and saving of time, it is

necessary to do the freezing as quickly as possible. The time for freezing depends upon how quickly the cold outer jacket can absorb the heat through the wall of the freezer barrel. This heat transfer may be made more quickly by lowering the temperature in the jacket or by making it possible for the heat of the mix to be transferred more readily through the wall of the jacket. The conductivity of this wall is determined by a number of factors, the first of which is the kind of metal. Copper has a higher



*Courtesy Creamery Package Mfg. Co.*

FIG. 97.—Cutaway of Horizontal Brine Freezer.

conductivity than iron or steel and gives a higher rate of heat transfer, but lacks durability. The thickness of the wall is also a determining factor, since doubling its thickness reduces the rate of heat transfer by one-half. Another and perhaps the most important factor is the film of frozen cream which tends to collect upon the inside of the freezer barrel. This film has a much lower heat conductivity than metal and acts very much as an insulator. If the blades of the scrapers do not keep this film scraped off well, there is a great reduction in the rate of heat transfer and consequently a longer time required for freezing. It is

important, therefore, to make certain that the blades of the scraper fit the barrel of the freezer perfectly throughout their full length. With many types of freezers, there is a tendency for the beater to become sprung out of shape, resulting in a poor fit. In order to overcome this difficulty, some freezers employ scrapers made of short sections not over 10 ins. long. This prevents the whole blade from going out of adjustment. The centrifugal force of the revolving dasher, together with the action of the mix against the blades, is supposed to hold the scrapers against the barrel of the freezer. This has not always been found sufficient, especially with low-speed dashers and low-viscosity mixes. In certain instances, springs have been used to assist in this function. Dull blades also cause a building up of the frozen film on the inside of the freezer barrel. The importance of these factors in the freezing operations makes it desirable to inspect the blades at frequent intervals to make certain that they are properly adjusted and sharp. The dasher may be sharpened by draw filing. Care should be taken to file only the high spots and not to take off any more metal than necessary. The use of Prussian Blue for marking the spots is to be recommended and will indicate the high spots where the blue has rubbed off. Another method which is sometimes used is the placing of an electric lamp inside the freezer so that the blade is between the eye and the lamp. The light will then show through wherever there are low spots.

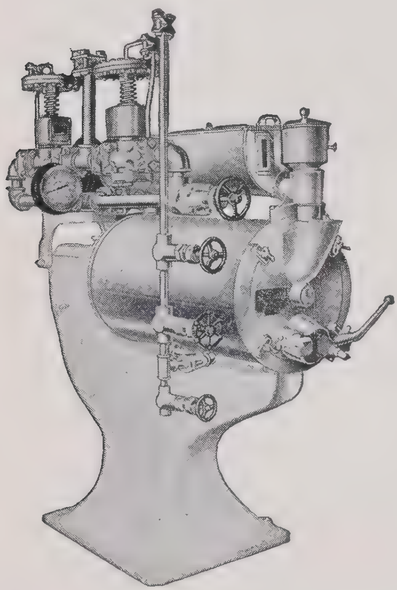
Care should also be taken to keep the inside of the freezer barrel as smooth and free from dents as possible, since a dent will tend to raise the blade from contact through its entire length. If the dent is outward, a frozen film will accumulate in the depression, causing a reduction in heat transfer. In a number of instances on record, the total time of freezing has been decreased as much as five minutes by straightening the dasher and sharpening the blades. The speed of the dasher is another important factor governing the speed of freezing. It is a well-known fact, and has been mentioned before under the general subject of heat transfer, that it is necessary to keep the liquids moving rapidly on two sides of a wall, if heat is to be transferred readily. Therefore, the speed of the dasher must be such that the frozen film is rapidly removed and thrown toward the center of the freezer to be replaced by the warmer mix. Another factor of importance is the rate of flow of the brine through the freezer in a brine type of freezer. In order for the heat to be absorbed readily, it must be removed readily by the brine. Therefore, a good quantity of brine, usually not less than 15 gals. per minute for a 40-qt. freezer, should be circulated, and the temperature *rise* in the brine should not be over 2° F. for best results, the lower temperature being preferred.

TABLE XCVI

Average Brine Requirements for Various Makes of Freezers

| Size of Freezer, Quarts | Gallons per Minute | Size of Freezer, Quarts | Gallons per Minute |
|---|---|---|---|
| 40 | 18–25 | 100 | 55–65 |
| 60 | 25–30 | 120 | 60–75 |
| 80 | 30–35 | 160 | 80–100 |

With the direct-expansion type of freezer, Fig. 98, it is necessary to have sufficient compressor capacity to handle the ammonia vapor as fast as it is formed. The temperature in the jacket is determined very largely by the back pressure on the refrigeration machine or by the pressure as shown on the low-pressure gauge of the freezer. There is also a definite relationship between the pressure and the temperature at which ammonia vaporizes; it must vaporize before heat is taken up in the freezer. The flooded system of refrigeration, which is used, makes necessary an accumulator to prevent the return of liquid ammonia to the compressor. The temperatures can be very readily controlled by means of controlling the pressure of ammonia in the freezer. The efficiency of the direct-expansion freezer is much greater than that of the brine type, because there is no loss in the brine tank and because the connections that are subject to refrigeration losses are much shorter. It has been found that a $1\frac{1}{2}$-ton refrigeration machine will operate a 40-qt. direct-expansion freezer, while 3-5-ton capacity is required where the brine system is used. The direct expansion freezer, which is a relatively new development, promises to become quite popular in the industry.



*Courtesy J. G. Cherry Co.*

Fig. 98.—Direct Expansion Freezer.

The whipping process is usually carried on after the freezing medium has been turned off. When this method is used, it is very important to be sure that the refrigeration is entirely shut off, as otherwise the whipping takes a much longer time. Investigation at the University of California has shown that the time required for whipping, as well as for freezing, is also affected materially by the speed of the dasher. In computing the heat extracted in making ice cream, the following average figures may be used, although there is a variation depending upon the type of ice cream frozen.

| | |
|---|---|
| Specific heat of milk | 0.93 |
| Specific heat of cream | 0.70 |
| Specific heat of mix | 0.80 |
| Specific heat of hard ice cream | 0.42 |
| Heat of fusion of ice cream | 80 B.T.U. |

It may be considered that one-half of the heat of fusion is removed in the freezer.

Further care of the freezer consists in using the proper lubricant in the gear box and making certain that it always has a sufficient amount. Bearings should be kept tight and in alignment. Where silent chains are used for driving the machine, their adjustment is also important, as chains that are too loose or too tight wear rapidly. In some makes of machines, special care must be taken with the beater bearings, since poor adjustment might affect the position of the dasher inside the freezer. The packing where the beater shaft goes through the end of the freezer barrel should be kept soft and in good shape. It should be renewed frequently for sanitary reasons.

**Protection of Equipment from Corrosion.**—Corrosion of ice cream equipment is rapid because of the presence of moisture and brines. Much of this can be prevented by treatment, as has already been mentioned under brines. On general equipment, corrosion may be prevented by the use of certain materials and methods. Surfaces that are alternately wet and dry are very much subject to corrosion; if they can be so arranged as to be always submerged or always dry some of this trouble may be overcome. Coating the materials with paint is also a good method. Paint should not be expected to last indefinitely but should be applied periodically, as required. Painting not only prevents corrosion but also improves the appearance of the plant. As a priming coat on metallic surfaces exposed to moisture, red lead is very efficient, although it requires several weeks to dry thoroughly and should be dry before further coats are applied. After this priming coat has been given, other colors may be used to produce the desired

effect. Zinc-base paints are considered superior to lead-base for this use. Surfaces exposed to high temperatures are well protected by the use of an asphalt base paint, but this is usually available only in black or other dark colors. The operator should not attempt to use lead and oil paints over asphalt paint, as the black will " bleed " through and the paint may not dry. Certain commercial preparations may be used on shafts and other bright parts. Lacquers for metallic surfaces are satisfactory, if they are renewed at frequent intervals. Most of the commercial preparations for this purpose are of a greasy or sticky nature and are really only slightly superior to common hard oil or cup grease. The lacquers have the advantage of giving a hard surface which does not collect dust. Light oils are of very little value in preventing corrosion except for very short periods of time. Steam-cylinder oil, 600W, however, is a very good coating for materials that are to be put away where the oil will not be rubbed off. A coating of white lead and tallow is good for treating bright-colored parts that are to be put in storage. This material forms a good protecting film and at the same time is easily removed.

Metallic coatings, such as zinc, tin, cadmium, and chromium are sometimes used. For protecting steel or iron, zinc is much superior to tin. Therefore, galvanized iron is much superior to tinned iron from the corrosion standpoint. Tinned copper is perfectly satisfactory, except that the cost of copper precludes its use in most instances.

**Pasteurizers and Heaters.**—Pasteurizers and heaters are merely apparatus for the transfer of heat from a hot substance, such as hot water or steam, to a substance such as milk or ice cream mix. If there is to be quick and efficient heat transfer, it is necessary to have sufficient heating surface. A good pasteurizer should have the heating surface so large that the heating medium may be only a few degrees hotter than the maximum temperature to which the mix is to be heated. It is also of importance that both the heating medium and the mix be properly agitated, as the lack of agitation will cause an insulating film to build up next to the heat-transfer wall and will result in decreased efficiency. For example, with agitation of the brine in a brine tank, the pipe will absorb 40 B.T.U. per square foot per hour per degree difference in temperature, while without agitation it will absorb only 20 B.T.U.

For pasteurizing mix, the open-type heater has some advan ages in that it is usually less expensive and that it may help to remove odors from the mix. It has the disadvantage, however, of allowing considerable evaporation. Furthermore, a certain amount of contamination and oxidation may take place through contact with the air. An internal heater is somewhat more difficult to clean but overcomes a number of the difficulties mentioned under external heaters. Many pasteurizers are

of the rotating-coil type, with the heating medium carried in the coil. These have given very good satisfaction in most plants but are somewhat difficult to clean properly. Glass-lined vats, which are an improved type of heater, carry the heating medium in a double-walled jacket, surrounding the inner tank. This type of vat is more easily cleaned. The above type of pasteurizers are almost always used with the batch method of pasteurizing. However, combinations of three or four batch pasteurizers may be used to give a continuous method of pasteurizing.

There are also so-called continuous or flash pasteurizers, in which the milk or mix is heated to a temperature of around 165–175° F. in a very short time, perhaps a half minute, and carried continuously through the machine. The heat necessary for pasteurizing a certain amount of mix may be calculated from the formula given below.

Weight of mix multiplied by specific heat, multiplied by temperature rise, equals heat necessary for pasteurization. It may be usually considered that the amount of heat given up by one pound of steam is between 900 and 1000 B.T.U., depending upon the initial pressure and temperature and the final temperature after it has been condensed. For general calculations, the figure 950 B.T.U. might be used.

The efficiency of the pasteurizer should also be considered. Although this varies with different types of heating apparatus, 70 per cent might be taken as an average value. To find the actual heat which must be supplied to the pasteurizer, the following formula should be used:

$$H = \frac{W \times \text{specific heat} \times \text{temperature rise}}{.70}$$

$$\begin{aligned} W &= \text{Weight of mix heated} \\ \text{Specific heat} &= \text{specific heat of mix heated} \\ \text{Temperature rise} &= \text{temperature rise of mix heated} \\ .70 &= \text{efficiency of heater.} \end{aligned}$$

**Use of Exhaust Heat for Pasteurizing.**—Many plants have considerable exhaust steam from engines and turbines, which would be wasted if it were not used for processing. Pasteurizing is carried on at a temperature of about 145° F. and, therefore, hot water at 150–160° F. can be used for heating the mix. In some plants, a water jacket or water coil is placed on the exhaust pipe of a gas engine and the exhaust heat carried to a suitable hot water tank.

**Coolers.**—Cooling apparatus is very similar in principle and construction to heaters. Since the temperature differences, however, are usually smaller, more cooling surface is required for quick cooling than for quick heating. The various types of coolers are similar to heaters, namely, vat and tubular.

The cooling medium and the liquid to be cooled should both be well agitated. Use should be made of the counter-current principle where possible. This principle is best illustrated by the following diagram:

It will be noted that with this method the hot mix enters at the top of the cooler and the cold mix leaves at the bottom. The cooling medium will enter at the bottom and leave at the top. Thus, the direc-

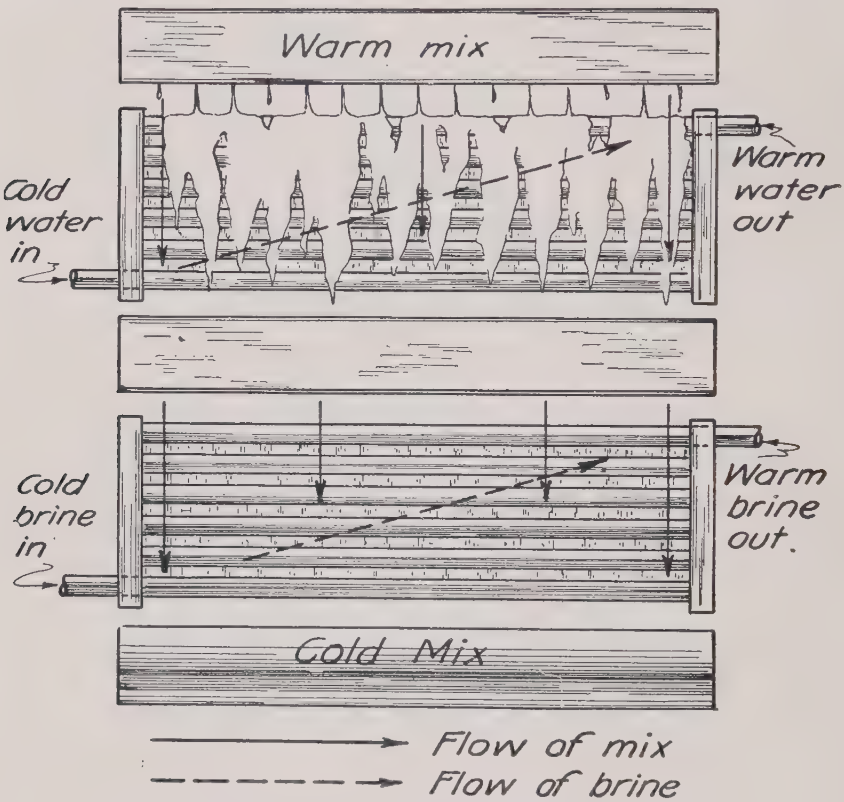


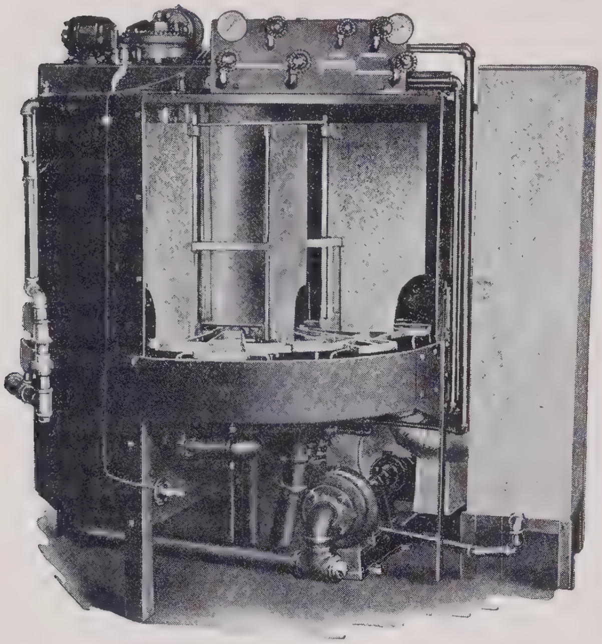

FIG. 99.—Counter Current Principle of Cooling.

tion of the flow of the cooling medium is counter to that of the medium which is to be cooled. By this method, it is possible to cool to within several degrees of the initial temperature of the cooling water, whereas if the direction were reversed this would not be possible. The cooling medium at its coldest is brought in contact with the coldest part of the liquid to be cooled.

When cooling with the double-walled type of glass-lined vats, considerably more time is required than with the tubular cooler. By using

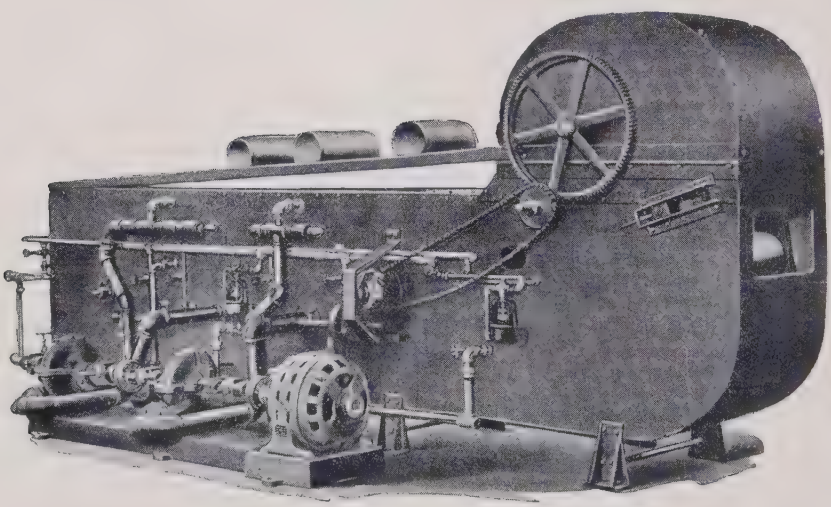
the spray instead of the flood method, a saving of approximately 16 per cent in time and water may be made. With the former, the cooling medium is sprayed in a thin layer along the outside of the inner wall of the tank and is removed as quickly as it reaches the bottom of the cooling chamber. With the latter, the water is allowed entirely to fill the space within the cooling chamber. This emphasizes the necessity of using a large opening at the bottom of the vat for removing the cooling water and prevented its backing up in the cooling compartment. Internal tubular coolers have the advantage over the external tubular type that the milk or mix does not come in contact with the air and is thus saved from evaporation and oxidation. If the cooler has an expansion head, it may be sterilized by connecting up with a steam line. This is an advantage from a sanitary standpoint.

**Can Washers and Driers.**—A number of mechanically operated can washers have been developed during the past fifteen years, and practically every large ice cream manufacturing plant has use for one. Can washers might be classified in several different ways: first, as to the method of driving the jets; and second, as to type. Most can washers have a number of different treatments for the can as it goes through the machine, each treatment being somewhat as follows: First, a preliminary rinse with either warm or cold water; second, treatment with one or two wash solutions at a temperature of approximately 150° F.; third, a treatment with hot sterile water at a temperature of 185–200° F.; fourth, a treatment with a live steam jet for sterilizing purposes; fifth, a treatment with hot air for the purpose of drying the can. A good can washer should turn out a can which is clean, sterile, and dry. Most can washers pass the can in a vertical, upside-down position over jets. In some of them, the action is continuous, while in others the can is stopped for a few seconds over each jet. The jets are usually operated by a motor-driven, centrifugal pump, although with some makes of machines a Duplex steam pump is used for this purpose. The electrically-driven pumps have the advantage of simplicity and freedom from frequent adjustment, while the steam-driven ones have the advantage that the exhaust steam may be used for heating the various solutions. With the latter type, however, great care must be taken to prevent the lubricating oil which is in the steam from getting in the wash tanks. From a number of observations, it has been found that this causes a sticky, grimy deposit on the necks of the milk cans, which is very objectionable. Figures 100 and 101 show typical, continuous can washers, operated by electrically-driven pumps. The rotary can washer is built on practically the same principle as the straight-away types, except that it has a circular form and that the cans are placed in the



*Courtesy Rice & Adams Co.*

FIG. 100.—Rotary Can Washer.



*Courtesy Rice & Adams Co.*

FIG. 101.—Ice Cream Can Washer.

machine and taken from it at the same point, thus enabling one man to operate the machine. With the straight-away types, it is customary to have one man place the cans in the machine and another to take them out, unless an automatic can unloader is used in connection with a roller transfer system.

The rotary machine will handle cans that are battered and out of shape much better than will the straight-away, since in the latter the cans that are badly out of shape are likely to fall over.

**Intermittent Versus Constant Jet Operation.**—With some types of washers, the jets are operated continuously, while with others they operate only for the time the can should be in position above the jet. In the latter type, the jets are operated by a trigger; in the former, by a cam shaft. If the can washer is operated at full capacity, there is not much advantage in having the intermittent operating jets, but it will save considerable water and steam if the washer is operated at part capacity.

**Cost of Operation.**—The University of California has conducted experiments with various types of can washers under commercial and test conditions and found a considerable difference in the electrical, steam, and water consumption of various types of machines. The following table shows some of the results obtained from this investigation.

TABLE XCVII

POWER CONSUMPTION OF CAN WASHERS

| Type of Washer | Capacity Cans per Hour | Used per 100 Cans Washed | | |
|---|---|---|---|---|
| | | Pounds steam | Gallons water | K.W.H. electricity |
| Rotary (with steam pump) | 300 | 500.6 | 361 | .271 |
| Straight away | 385 | 274.0 | 85 | .924 |
| Rotary | 240 | 216.0 | 89 | 1.100 |

**Factors to be Considered in the Care and Operation of Can Washers.**—It has been found that, in securing good results, one of the most important considerations is that of the temperatures of the washing and sterilizing solutions. If these are not properly maintained, the cans will not be thoroughly washed and sterilized. Experiments have shown that the bacterial count on 10-gal. milk cans has been dropped from several thousand per cubic centimeter[4] to practical sterility by maintain-

[4] Bacteria per c.c. of a 400 c.c. solution used in rinsing the can.

ing the temperature of the sterilizing solution at 190° F. instead of 150° F. It is also of much importance to keep all jets thoroughly cleaned. There is a great tendency for strings, casein, and other foreign material to collect in the jets; cleaning at least every other day, and preferably every day, is, therefore, to be recommended. From actual experiments it has been found that the bacterial count has been dropped from 250,000 per c.c. to 6 and 8 by cleaning the jets of a badly stopped-up can washer.

The strainer over the suction lines to the pumps should also be kept clean because if it is allowed to become stopped up, the jets cannot function properly.

**Sterilizers.**—Sterilization of utensils about the ice cream plant may be accomplished in a number of different ways. The two most important are by the use of hot water or steam and by chemicals. The hot water and steam are used more than the chemicals, since the utensils may be easily submerged in hot water or placed in a steam chamber. If steam is used, the temperature may be varied by changing the pressure or by superheating the steam. Reference to the steam table will show that the temperature varies with the pressure. For instance, at atmospheric pressure, the steam will have a temperature of 212° F.; at 50 lbs., 287° F., and at 100 lbs., 320° F. If it is necessary to obtain a very high temperature, and if at the same time the apparatus will not withstand high-pressures, the temperatures may then be obtained by superheating the steam. For small ice cream plants or receiving stations, a small self-contained dairy sterilizer may be used. This type has been used on farms in California for a number of years and has been found very useful. It may be heated by means of an oil burner or an electric heating element. One of the latest type of dairy farm sterilizers is equipped with an electric heating element and an automatic thermostat, which turns off the power as soon as the proper temperature is reached. The maximum temperature obtained in such a sterilizer is about 212° F. The cost of operation is very low, being about 5 to 7 cents per batch for the four-can size. The better types are made to operate with a small amount of water, usually from 10 to 20 lbs. They are insulated against heat losses.

Sterilization of utensils by means of chemicals is sometimes necessary where it is impossible to use heat. Sodium hypochloride solutions are most commonly used for this purpose. The solution may be purchased already made up or can be easily manufactured by means of a suitable hypochloride cell. In the latter instance, common salt water is held in containers through which a direct current of electricity is passed. Chemical action takes place, with the resulting formation of sodium

hypochloride. This material is often used for sterilizing rubber parts, which will not stand high temperatures, and milk bottles, after they have been run through a bottle washer.

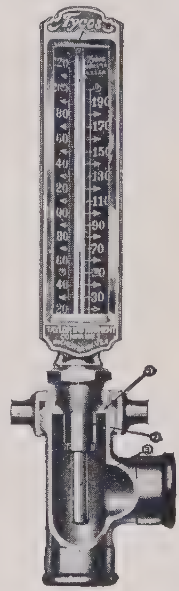
An investigation conducted by the State Department of Agriculture of the State of California shows that chemical sterilization is fairly effective in reducing bacterial counts, provided that there is no organic material present. The necessity of thoroughly washing all equipment and of removing all organic matter, such as milk residues, before attempting to sterilize with a chemical solution, cannot be too strongly emphasized.

Other chemicals have been experimented with, and a number of commercial preparations are sold on the market. Most of them rely upon free oxygen or chlorine for their action and have somewhat the same characteristics as the sodium hypochloride manufactured from salt water.

Strong alkali solutions are sometimes used as sterilizing agents. Tests have shown that subjecting milk bottles to hot alkali solutions has a high sterilizing effect.

**Thermometers.**—The thermometer might be defined as an instrument for indicating or recording temperatures. Since temperature is very important in many of the operations carried on in the ice cream plant, thermometers are very widely used. There are many types for different purposes. Some of the more important will be discussed.

The commonest type of indicating thermometer is known as the chemical thermometer. It consists of a straight, hollow, glass tube with a bulb on one end filled with an expansible liquid, which expands or contracts in accordance with temperature changes. There are special industrial thermometers made up for special purposes. As a general rule, the industrial thermometer is built rather heavily and is attached to the apparatus with which it is to be used by means of a threaded connection. It is usually constructed with a heavy metal housing in order to protect the tube from breakage. Figure 102 shows a common type of industrial thermometer.




*Courtesy Taylor Instrument Company*

Fig. 102.—A Common Type of Industrial Thermometer Showing the Method of Attachment of Sanitary Tubing.

The long-stemmed thermometer is another modification, which has many uses about an ice cream plant. With this type of thermometer, the temperature in the bottom of the vat may be easily taken.

The index thermometer is somewhat different from the ordinary bulb-and-tube thermometer, since the temperature is registered by a hand passing over a dial in a manner similar to a steam gauge. It is more easily read than the bulb-and-tube type, and for some purposes is superior on this account.

The actuating medium of thermometers is usually mercury. This substance has a freezing point of −40° F. and a boiling point of 1000° F. Its expansion is practically uniform over the entire temperature range, and it is permanent. Some thermometers use spirits, consisting of alcohol or ether mixtures, in the place of mercury. These are often colored and on that account are easily read.

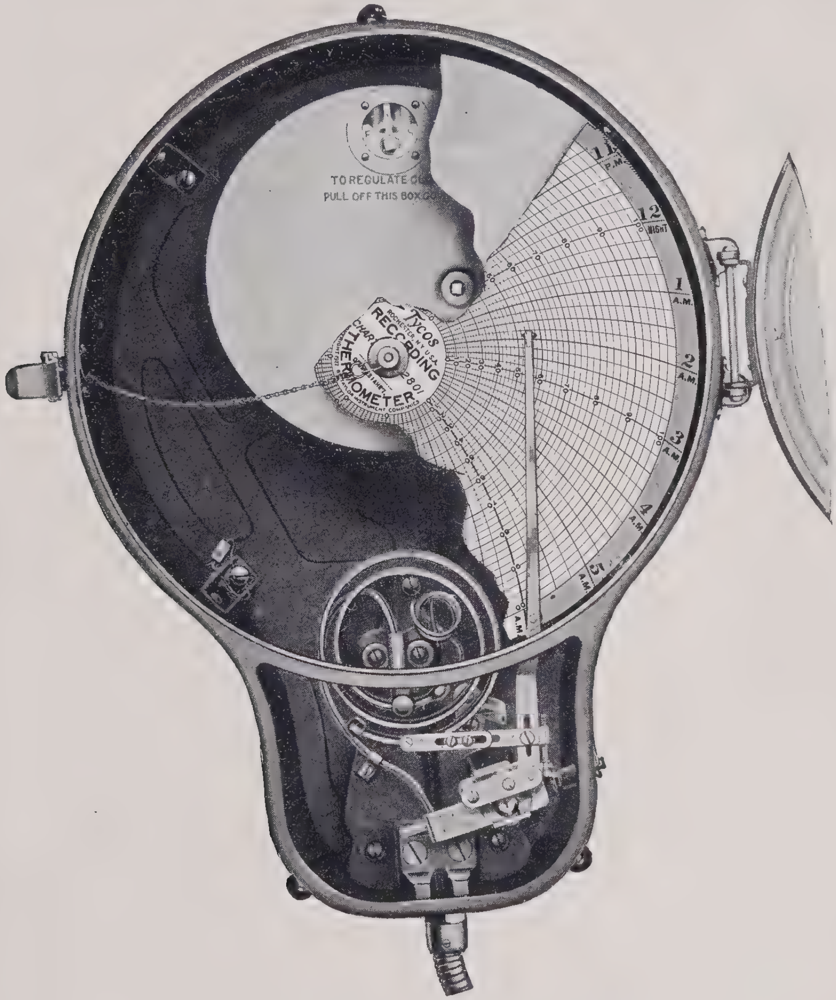
Thermometers, whether they are of the indicating or recording type, should be tested at suitable intervals. The best practice is to check them against a standard thermometer which can be purchased from reliable thermometer manufacturers. Checking should be made at the boiling and freezing points of water and at each 30° above 32° F. It is of special importance to check them at the critical temperature at which they are to be used. For example, if a thermometer is to be used in the pasteurizing vat, in which a temperature of 150° F. is the critical temperature, then the thermometer should be checked very closely at this temperature.

The engraved-stem thermometer has the scale divisions cut into the glass itself as the thermometer is tested. This is the most accurate and best quality of thermometer.

The most inexpensive thermometers use a printed scale which is attached to a holder near the thermometer support, just back of the thermometer tube, or within the thermometer tube. A good thermometer should be accurate throughout its range. Only one having a uniform bore is to be depended upon in this respect.

**Recording Thermometers.**—Recording thermometers are used to give a permanent record of the temperature throughout the process. This is a measure of protection both for the manufacturer and for the consumer of the product. The general construction of the recording thermometer is as follows: A hollow bulb containing a suitable liquid or gas which expands when heated is connected by means of a capillary tube to a hollow coil spring. This is connected by means of suitable rings to the pen arm. As the temperature rises in the bulb, a pressure is exerted in the hollow tube and spring, causing the spring to straighten out and thus moving the pen arm. The pen is attached to the end of the pen arm and bears upon a circular chart with suitable time and temperature graduations marked upon it. The chart is rotated by means of a clockwork motor. Certain modifications of this general type

of construction are found. Some instruments are what is known as the self-contained type, in which no bulb or capillary tube is used. With this instrument, which is used mostly for measuring the temperature of



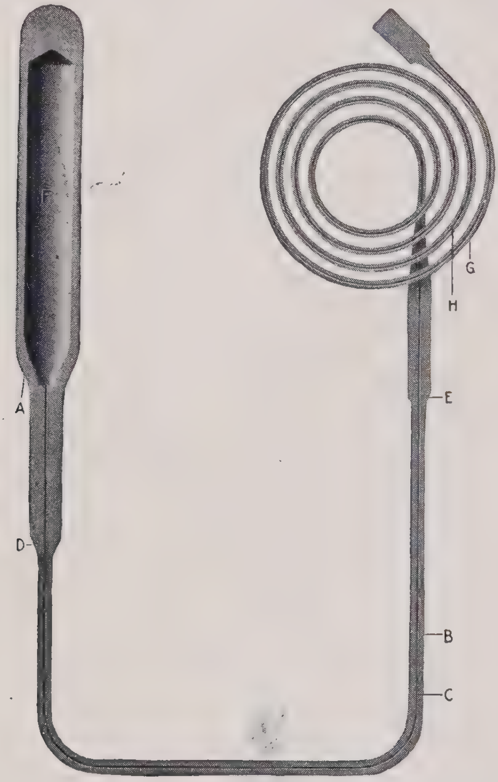

*Courtesy Taylor Instrument Company*

Fig. 103.—Cutaway of Recording Thermometer.

air and gases, the temperature changes act directly upon the hollow-coil spring.

Types of thermometers might be classified according to the actuating medium used inside the tube system. With mercury, which is very often

employed, it is necessary to use a steel tube and bulb. The latter is usually made with 0.015 in. bore, a small wire being drawn through this in order to decrease the size still further. It can be readily seen that sharp bends in the tubes are very likely to close this small opening and ruin the thermometer. The elevation of the bulb above the instrument makes no appreciable difference in the reading. A maximum of 25 ft. of capillary tube is furnished. Longer tubes are obtained only at a very much increased cost.




*Courtesy Taylor Instrument Company*

Fig. 104.—The Bulb, Capillary Tube and Expanding Coil of Recording Thermometer.

The vapor-tension type of instrument uses a volatile liquid, such as alcohol, ether, or some mixture of similar substances. This type of instrument has a lower pressure than the mercury-filled types, and because the liquids do not act on copper, a small copper tubing takes the place of the steel tube and bulb. It is possible to obtain tube systems up to 100 ft. or more in length. With this type of instrument the reading is affected by the elevation of the bulb with respect to the instrument. In ordering such thermometers, the difference in elevation should be specified.

Since volatile liquids do not have a uniform expansion rate, the charts, as a rule, are not uniformly graduated, as is the case with the mercury-filled type.

Gas-filled thermometers are sometimes used. Their characteristics are quite similar to those of the vapor-tension type. They are of special value in high-temperature work and in places where it is

necessary to have the bulb situated a considerable distance from the instrument.

**Management of Recording Thermometers.**—The installation of recording thermometers is important. Since they are delicate instruments, they should be mounted where they will be free from vibration, and where the capillary tube will be free from extreme changes of temperature as well as from danger of breaking. It is of special importance to place the bulb at a point where it will record the proper temperature. If it is set in a pocket where the circulation about it is poor, it will not record the true temperature of the liquid.

Care should be taken to keep the thermometer case closed at all times and to prevent moisture from entering. Ink should be applied frequently and in small amounts and should be wiped from the pen arm, since it causes corrosion. Only the best quality of recording-thermometer ink should be used, since this ink has the special property of slow drying and will not stop up the pen point as easily as ordinary ink. With some types of pen points, the ink is fed through a very small capillary tube. It is quite important to clean this out occasionally by means of a small wire. The clock should be wound regularly. Care should also be taken not to allow the bulb to become overheated, as this would cause a strain on the tube system which might result in its destruction. Most thermometers are equipped with a lock seal. Only authorized persons should be allowed to care for and regulate the instrument.

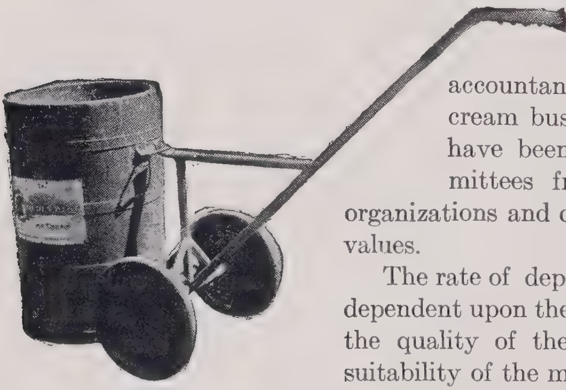
**Testing and Regulation.**—As recording thermometers frequently get out of adjustment, they should be checked for accuracy at suitable intervals. It is recommended that they be tested once every week or two weeks, depending upon the conditions under which they are used and the importance of the correct reading. The testing should be done in much the same manner as for an indicating thermometer. Care should be taken to have the thermometer bulb and the test-thermometer bulb very close together in a well-agitated liquid at the time readings are taken. Time should also be given for the recording thermometer to come up to the given temperature, since there is more of a temperature "lag" with a recording thermometer than with the average test thermometer.

**Temperature Regulators.**—There are many processes in which automatic temperature regulators can be used, thereby relieving the operators of a certain amount of responsibility and in many cases making possible closer control of temperatures. The direct acting temperature regulator consists of a diaphragm valve which is placed on the steam, brine, or water line, as the case may be, and which is operated by means of a bulb-and-tube system attached to the apparatus, the temperature

of which is to be controlled. When the temperature rises in the apparatus, pressure is built up in the tube system, causing the diaphragm valve to close. During a temperature drop, an opposite action takes place.

The air-controlled temperature regulator operates in much the same manner, except that the diaphragm valve is operated by air pressure which enters from the storage tank, opening a small air valve. The air leak is an important part of the controller, since if it is opened wide, the valve will open slowly and close quickly; while if it is nearly closed, the valve will open quickly and close slowly. The electrically controlled temperature regulator makes use of a thermostat and electrically operated solenoid valves for controlling the flow of the heating or cooling liquid.

**Depreciation.**—Depreciation of dairy machinery amounts to a considerable part of the cost of manufacture. The following table shows the commonly accepted depreciation rates which are used by cost accountants in the milk and ice cream business. Most of them have been worked out by committees from the various dairy organizations and can be taken as average values.



*Courtesy Walt's Welding Works*
FIG. 105.—Handy Tub Truck.

The rate of depreciation is very largely dependent upon the following factors: first, the quality of the machine; second, the suitability of the machine for the work it has to do; third, the care used in its operation and upkeep. It is a well-known fact that it would be expensive to use for heavy work a light machine which was continuously breaking, just as it would be expensive to use a small automobile engine to do the work of a tractor or truck engine.

Machinery in ice cream plants is subjected to very severe conditions because of the high moisture and the escaping ammonia vapors and brine solutions which are found there. For this reason, only the best quality of materials resistant to corrosion should be used in the construction of machinery. All exposed surfaces should be kept well painted. It is impossible for any paint to last indefinitely. Therefore, it is desirable to repaint equipment at least once or twice a year, in order to give good protection. Many small parts of machines can be tinned or galvanized to prevent rusting.

## TABLE XCV

### Depreciation on Dairy Equipment *

| Class of Property | Percentage Rate of Depreciation | Percentage of Questionnaire Vote |
|---|---|---|
| Buildings: | | |
| Brick-frame | 2 – 4 | 61 |
| Brick-steel | 2 – 3 | 65 |
| Concrete | 1½– 2½ | 40 |
| Frame | 3 – 5 | 72 |
| Elevators | 5 –10 | 72 |
| Machinery: | | |
| Refrigerating Machines | 5 –10 | 63 |
| Condenser Coils | 5 –10 | 59 |
| Compressed Air Machines | 5 –10 | 49 |
| Ice and Brine Tanks | 5 –10 | 52 |
| Expansion Coils | 5 –10 | 59 |
| Shell Coolers | 5 –10 | 55 |
| Ice Cans | 10 –15 | 61 |
| Ice Can Dumps | 10 –15 | 57 |
| Ice Cranes and Lifts | 10 –15 | 65 |
| Brine Pumps | 10 –15 | 54 |
| Refrigerated Rooms: | | |
| Expansion Coils | 10 –15 | 63 |
| Brine Coils | 10 –15 | 68 |
| Hardening Rooms | 10 –15 | 58 |
| Milk & Cream Storage Rooms | 10 –15 | 60 |
| Ice Storage Rooms | 10 –15 | 65 |
| Ice Cream Machinery: | | |
| Freezing Machines | 10 –15 | 53 |
| Brine Lines | 10 –15 | 60 |
| Pasteurizing Vats | 10 –15 | 63 |
| Holding Vats | 10 –15 | 64 |
| Ice Crushers | 10 –15 | 59 |
| Ice Conveyors | 10 –20 | 76 |
| Ice Elevators | 10 –15 | 57 |
| Tubular Coolers | 10 –15 | 65 |
| Homogenizers | 10 –15 | 60 |
| Pre-Coolers | 10 –15 | 62 |
| Sanitary Piping | 10 –15 | 55 |
| Can Washers | 10 –20 | 78 |
| Overrun Testers | 10 –15 | 57 |
| Mixers | 10 –15 | 64 |
| Brick-cutting Machines | 10 –15 | 60 |
| Miscellaneous Machines | 10 –15 | 67 |
| Chocolate-mixing Kettles | 10 –15 | 64 |
| Copper Kettles | 10 –15 | 66 |
| Hand Trucks | 15 –20 | 40 |
| Power Equipment: | | |
| Boilers | 5 –10 | 55 |
| Boiler Feed Pumps | 10 –15 | 70 |
| Steam Engines | 5 –10 | 60 |
| Gas Engines | 6 –10 | 58 |
| Power Equipment:—(*Cont.*) | | |
| Generators | 5 –10 | 60 |
| Motors | 5 –10 | 62 |
| Electric Wiring | 10 –15 | 66 |
| Steam Piping | 5 –10 | 52 |
| Water Lines | 5 –10 | 57 |
| Gas-producing Tanks | 10 –15 | 76 |
| Shafting and Pulleys | 10– 15 | 64 |
| Belting | 10 –20 | 52 |
| Containers: | | |
| Brick Slabs | 20 –33⅓ | 69 |
| Brick Caves or Tanks | 20 –33⅓ | 74 |
| Cans, Steel | 20 –33⅓ | 71 |
| Cans, Tin | 20 –33⅓ | 68 |
| Tubs | 20 –33⅓ | 76 |
| Cabinets | 20 –33⅓ | 72 |
| Delivery Equipment: | | |
| Fords | 25 –33⅓ | 72 |
| 1 Ton or Less | 25 –33⅓ | 76 |
| 1½ to 3 Tons | 20 –25 | 57 |
| Over 3 Tons | 20 –25 | 55 |
| Electric: | | |
| Chassis | 6 –15 | 20 |
| Battery | 15 –25 | 73 |
| Truck Bodies: | | |
| Open Type | 10 –20 | 27 |
| Refrigerator | 15 –25 | 63 |
| Touring Cars: | | |
| Type | 20 –25 | 53 |
| Wagons: | | |
| Open Platform | 10 –20 | 59 |
| Refrigerator | 10 –20 | 75 |
| Open-style Packing Wagons | 10 –20 | 70 |
| Horses | 10 –16 | 50 |
| Harness | 15 –20 | 50 |
| Office Furniture and Fixtures: | | |
| Safes | 5 –10 | 79 |
| Office Machines | 10 –20 | 92 |
| Desks, Tables and Chairs | 10 –20 | 78 |
| Repair Department: | | |
| Lathes, Drill Presses, Planes, etc. | 10 –15 | 74 |
| Tools | 22 –33 | 40 |

* From the Depreciation Report of the Cost Accounting Committee of the National Association of Ice Cream Manufacturers, S. T. Nivling, Chairman, presented at the Twenty-second Annual Convention at Cleveland, O. Data obtained from a questionnaire sent to members.

## TABLE XCIX

### Condensed Steam Tables

Gauge Pressure. Properties of Saturated Steam, 0 to 100 Lbs. Gauge

| Pressure, Pounds Gauge | Pressure, Pounds Absolute $P$ | Temperature, Degrees Fahr. $t$ | Specific Volume, Cubic Feet per Pound $v$ or $s$ | Heat of the Liquid $h$ or $q$ | Total Heat of Steam $H$ |
|---|---|---|---|---|---|
| 0 | 14.7 | 212.0 | 26.79 | 180.0′ | 1150.4 |
| 5 | 19.7 | 227.2 | 20.38 | 195.3 | 1155.9 |
| 10 | 24.7 | 239.4 | 16.49 | 207.7 | 1160.2 |
| 15 | 29.7 | 249.7 | 13.88 | 218.2 | 1163.7 |
| 20 | 34.7 | 258.8 | 11.99 | 227.4 | 1166.7 |
| 25 | 39.7 | 266.9 | 10.57 | 235.6 | 1169.3 |
| 30 | 44.7 | 274.1 | 9.45 | 243.0 | 1171.5 |
| 35 | 49.7 | 280.6 | 8.56 | 249.7 | 1173.5 |
| 40 | 54.7 | 286.7 | 7.82 | 255.9 | 1175.3 |
| 45 | 59.7 | 292.4 | 7.20 | 261.8 | 1176.9 |
| 50 | 64.7 | 297.7 | 6.68 | 267.2 | 1178.4 |
| 55 | 69.7 | 302.6 | 6.23 | 272.3 | 1179.7 |
| 60 | 74.7 | 307.3 | 5.83 | 277.1 | 1181.0 |
| 65 | 79.7 | 311.8 | 5.49 | 281.7 | 1182.2 |
| 70 | 84.7 | 316.0 | 5.18 | 286.1 | 1183.3 |
| 75 | 89.7 | 320.1 | 4.91 | 290.3 | 1184.3 |
| 80 | 94.7 | 323.9 | 4.67 | 294.3 | 1185.3 |
| 85 | 99.7 | 327.6 | 4.441 | 298.1 | 1186.3 |
| 90 | 104.7 | 331.2 | 4.241 | 301.8 | 1187.1 |
| 95 | 109.7 | 334.6 | 4.058 | 305.4 | 1180.0 |
| 100 | 114.7 | 337.9 | 3.890 | 308.8 | 1188.8 |

## TABLE C

### Condensed Table of Properties of Saturated Ammonia-Pressure

| Pressure, Pounds Gauge per Square Inch | Temperature, Fahr. | Total Heat of Liquid | Latent Heat of Evaporation | Total Heat of Vapor |
|---|---|---|---|---|
| 0 | −28.51 | +12.3 | 589.1 | 601.4 |
| 4.5 | −17.61 | 24.0 | 581.6 | 605.6 |
| 9.5 | − 8.77 | 33.4 | 575.2 | 608.6 |
| 14.5 | − 1.27 | 41.5 | 569.6 | 611.1 |
| 20.0 | + 5.89 | 49.3 | 564.2 | 613.5 |
| 25.0 | 11.66 | 55.6 | 559.7 | 615.3 |
| 30.0 | 16.88 | 61.3 | 555.6 | 616.9 |
| 35.0 | 21.67 | 66.5 | 551.8 | 618.3 |
| 40.0 | 26.09 | 71.4 | 548.1 | 619.5 |
| 45.0 | 30.21 | 75.9 | 544.7 | 620.6 |
| 50.0 | 34.07 | 80.2 | 541.5 | 621.7 |
| 55.0 | 37.70 | 84.2 | 538.4 | 622.6 |
| 65.0 | 44.40 | 91.6 | 532.6 | 624.2 |
| 75.0 | 50.47 | 98.4 | 527.3 | 625.7 |
| 85.0 | 56.05 | 104.8 | 522.1 | 626.9 |
| 95.0 | 61.21 | 110.5 | 517.3 | 627.8 |
| 105.0 | 66.02 | 116.0 | 512.8 | 628.8 |
| 115.0 | 70.53 | 121.1 | 508.4 | 629.5 |
| 125.0 | 74.79 | 126.0 | 504.3 | 630.3 |
| 135.0 | 78.81 | 130.6 | 500.3 | 630.9 |
| 145.0 | 82.64 | 135.0 | 496.4 | 631.4 |
| 155.0 | 86.29 | 139.2 | 492.7 | 631.9 |
| 165.0 | 89.78 | 143.2 | 489.0 | 632.2 |
| 175.0 | 93.13 | 147.1 | 485.5 | 632.6 |
| 185.0 | 96.34 | 150.9 | 482.0 | 632.9 |
| 210.0 | 103.88 | 159.8 | 473.7 | 633.5 |
| 235.0 | 110.80 | 168.0 | 465.8 | 633.8 |
| 260.0 | 117.22 | 175.7 | 458.2 | 633.9 |

* Bureau of Standards Tables of the Properties of Ammonia.

The operator can materially increase the life of his machines by reporting promptly to the engineer any trouble, and making certain that it is remedied. A certain amount of pride in his machine is necessary on the part of the operator if he is to get the best results. Plant managers should make certain that the operators understand thoroughly the machines they are to operate and know how to care for them properly. Ignorance of machinery probably causes more destruction than any other one single factor in the plant.

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## CHAPTER XII

# MERCHANDISING

Many merchandising plans are put forth by various manufacturers in the ice cream industry. Some of these schemes are successful; others meet with decided failure. An examination of articles regarding them is sufficiently convincing that no fundamental principles have governed the formulation of new sales methods. It is obviously quite impossible to devise the ideal method of merchandising ice cream. The object of this chapter is simply to give the principles of modern merchandising and to indicate the adaptation of these principles to the selling of ice cream. It is believed that with these principles in mind, the ice cream manufacturer should be able to judge new merchandising methods and to determine their practicability before actually going to the expense of putting them into operation. This does not mean, however, that successful plans outside of these principles may not be evolved. A recent example of such a diversion is given in the apparently successful policy used by the Realsilk Hosiery people, who employed a house to house method, which up to that time was contrary to all the accepted methods of marketing such an article. The selling methods of Fuller Brushes offer a similar example.

There are five distinct steps in the formulation of a merchandising policy. With an understanding and appreciation of these, the manufacturer with goods to sell will have a better conception, a broader view of the field that marketing occupies. These five steps are as follows: (1) The classification of the goods, which largely determines their method of distribution. (2) Ascertaining the motives which lead the consumer to purchase the goods. A knowledge of the consumer's buying motives is essential, if the seller is to make an intelligent appeal to him. (3) The formation of the organization that is to carry out the merchandising plan. (4) Physical handling, that is, the policy governing the handling of the goods, the rate of stock turn, stock control, and similar problems. (5) The determination of the price policy. This will be governed by a number of conditions: competition, prevailing prices for the same commodity, the contemplated volume of production, and the cost of production over a period of time.

All merchandise may be divided into two groups: industrial goods

and consumer's goods. The former consist of raw or semi-manufactured materials, equipment, supplies, and other goods that are sold in large lots to individual users for industrial purposes. The market for these products is usually clearly defined. Ice cream freezers are rightly classified as industrial goods. The manufacturer of such equipment knows just how many possible purchasers of his product there are. The only thing than can disrupt his plans is the starting of new enterprises in his line to stiffen the competition.

**Consumers' goods** are those that are sold in retail stores and of which every person is a potential buyer. Ice cream itself, for instance, may have 110,000,000 buyers in the United States, assuming that to be the present population. The merchandising plan of the two groups is quite dissimilar, inasmuch as the methods of distribution and the buying motives are so different. Industrial goods are purchased for business reasons, based on the suitability of the product to the purpose for which it is intended. Consumers' goods, on the other hand, are bought for personal reasons to satisfy personal wants.

Each of the above groups has its separate merchandising problems. The ice cream manufacturer is interested only in selling consumers' goods. These may be broadly classified, using the buying habit of purchasers as a basis, into (1) convenience goods, (2) shopping goods, and (3) specialty goods.

**Convenience goods** are those purchased in easily accessible stores. The buyer is generally familiar with the article he wants, and seeks to satisfy the want immediately in the nearest store. The unit sale is ordinarily not very large, and, as the want is felt at frequent intervals, the buyer is not justified in going far out of his way to satisfy it. Examples of convenience goods are cigars, magazines, confectionery, package groceries, and shaving soap. The task of the manufacturer of convenience goods is to stimulate buying motives and have his product on sale in as many stores and at as many convenient points as possible. Inasmuch as the buyer has felt the want before he enters the store, the task of the retailer is to have those goods on hand. In other words, the retailer of convenience goods stimulates patronage motives by having on hand the articles for which the manufacturer has already created a demand. Since the unit sale is small, the retailer may substitute in some cases, but the customer is not likely to come back if another store close by can satisfy his want. Furthermore, when the retailer substitutes an article for the one requested, he must assume the responsibility. If that for which the customer has asked is unsatisfactory, the consumer blames the manufacturer. But if the substitute is unsatisfactory, he blames the dealer.

Several years ago the United States Department of Agriculture attempted to stimulate the marketing of butter and eggs by parcel post. The result in nearly every case was unsatisfactory. Butter and eggs are convenience goods, the want for which will not be anticipated sufficiently far in advance for the consumer to order ahead. Furthermore, he will not take the trouble to order by mail an article of so small a unit price, when he can purchase it at the corner grocery. Moreover, the venture did not always prove to be profitable for the producer. In marketing directly, he had to assume the functions of the middleman or retailer. The cost of selling and getting the goods to the consumer took a good share of the profit. In addition, the inability of a producer to give the service commonly expected from the retailer inevitably leads to dissatisfaction.

**Shopping goods** are purchased only after a comparison of price, quality, and style. These are customarily sold in dry goods and department stores, where women are the principal buyers. They are seasonal commodities, and although the want may have been felt, it can usually be deferred until the consumer finds something that is satisfactory both in price and quality. The task of the retailer of the shopping goods, therefore, is to carry a large variety of the seasonal styles in quite a range of price and quality. The object, of course, is to have such a great variety that the customer will not find it necessary to go to other stores to make comparisons but will shop within the one store. The manufacturer of shopping goods must anticipate style tendencies and make a variety of goods in price and quality to attract the department store buyer.

**Specialty goods** are goods that have such a special attraction to the buyer that he will go out of his way to make the purchase. In many instances, the buyer has decided upon the article he wants before going to the store and so makes the purchase without "shopping around." Examples of specialty goods are men's clothing, men's shoes, automobiles, and phonographs. The manufacturer of specialty goods must be reaching out constantly for new customers, for the unit sale is usually large and the purchases are made infrequently. Obviously, such a plan necessitates a great deal of advertising both by the manufacturer and the retailer. The manufacturers of specialty goods commonly sell their product through exclusive agents. When an agent is granted sole selling rights in a certain section, it is assumed he will push the article aggressively. To induce exclusive agents to advertise more extensively, the manufacturers sometimes assume a certain percentage of the cost.

A classification of this kind cannot, of course, include all lines of merchandise. The dairyman will immediately see that market milk

has no place in it. Market milk is sold from wagons and demands an entirely different scheme of merchandising, which will not be discussed here. An intelligent merchandising program must, therefore, first determine the classification of the product so that the method of distribution may be determined.

Should the manufacturer of ice cream decide to make a fancy product or individualize it to such an extent that it is different from the ordinary commercial ice cream, then he must market it as specialty goods through his own stores or exclusive agents. He must expect, and try to induce, the consumer to go out of his way to purchase his product. Such a plan will not result in a large volume of sales because of the necessarily restricted territory within which ice cream must be sold.

**Trading Up.**—The large ice cream firms with separate catering departments customarily market their fancy products as specialty goods. Many firms take orders directly from the consumer for these. One firm is known to have established an office and display room in the best part of town simply to take orders for the catering department.

Fancy ice cream has a certain value to the large manufacturer from a merchandising point of view, in that it tends to lend prestige to the other products. There are many instances where firms have put out a very superior article in order to advertise their cheaper and better-selling products. Such a practice is known as "trading up." The opposite thing, that is, "trading down," results when the maker of a high-class product puts out a cheaper article. The cheaper one usually proves to be the better seller at the expense of the high-class one. The lowest-class product sold under a trade name sets the reputation for that trade name, irrespective of the "quality goods" sold under the same brand.

The large bulk of ice cream as it is sold to-day must fall under the classification of convenience goods. It is purchased frequently at easily accessible stores. Repeat purchases constitute a large percentage of sales. The consumer, in the case of convenience goods, usually seeks to purchase immediately the want is felt, a case exactly opposite that of the specialty goods, where the consumer may contemplate his purchase for some time after the want is felt. The cost per unit of convenience goods is usually too small to justify the consumer's going far out of his way to satisfy his want. Obviously, a merchandising plan of convenience goods must take these facts into consideration, and the manufacturer must have the goods on sale in as many conveniently located stores as seems practicable. That this has been the tendency among ice cream manufacturers is amply demonstrated by data compiled by the National Association of Ice Cream Manufacturers in their second Pro-

duction and Distribution Survey. Their statistics show that there are six principal dealer outlets.

| Classification | Number of Dealers * | Volume of Sales † |
|---|---|---|
| | Per Cent | Per Cent |
| Confectionery stores.......... | 30.25 | 27.8 |
| Grocery stores............... | 18.95 | 11.1 |
| Drug stores.................. | 16.30 | 29.2 |
| Wayside stands.............. | 10.16 | 3.8 |
| Hotels and restaurants....... | 7.99 | 12.8 |
| Cigar stores................. | 3.05 | 2.1 |
| Unclassified................. | 13.30 | 13.2 |
| | 100.00 | 100.0 |

* Based on the report of 588 ice cream plants serving 79,704 dealers.

† Based on the report of 240 typical ice cream plants throughout the country having a combined total output of 22,099,921 gals.

It must be realized, of course, that the manufacturer is carrying his distribution to extremes when it becomes necessary to take on customers who later prove to be non-profitable stops.

The next point in the merchandising program is to determine the selling points of the product. "What," asks the manufacturer, "are the best appeals to use in advertising my product?" In arriving at an answer, the manufacturer must attack the question from the other end. He must determine why that product is bought by the consumer, and what motives lead the consumer to buy. Having once determined those motives, a proper appeal can be made to them. A study by Copeland[1] of the consumer's buying motives, based upon actual conditions, has been a great help in solving merchandising problems. He divides the existing buying motives into two classes: emotional and rational:

> Emotional buying motives have their origin in human instincts and emotions, and represent impulsive or unreasoning promptings to action. Purchases are stimulated through these motives, not by an appeal to reason but by arousing the desires of the consumer to satisfy those instincts and emotions. Rational buying motives are those which are aroused by appeals to reason. When these appeals are used, it is expected that consumers will make their purchases only after reflection and the use of their powers of reason.

[1] Copeland, M. T., Principles of Merchandising. A. W. Shaw Co., 1925.

Under both classes, he includes all of the present buying motives now being used. Of the emotional group, there are three which may properly be used in an ice cream appeal. The first is called maintaining and preserving health. This goes back to the innate instinct of self-preservation and may be used in ice cream advertising in connection with the present knowledge of the food value of ice cream. The second motive is termed "satisfaction of the appetite." This is the universal desire for food and drink to which national advertisers appeal in selling food products. The third, "pleasing the sense of taste," is an appeal which emphasizes the flavor, quality, or savor as perceived by the palate. It is believed that the last is the strongest buying motive the ice cream manufacturer can use. The fact that the highest percentage of ice cream is sold in the hot summer months, when it is eaten solely to please the sense of taste is sufficient demonstration of the strength of this appeal to taste. The present tendency to emphasize in advertising the food value of ice cream does not seem so effective. The ordinary individual on the street, if asked why he buys a dish of ice cream, would give as his reason, not that he believes ice cream to be high in food value and a good thing for him to eat, but that he likes the taste. The appeal to the buying motive of maintaining and preserving health is by no means wasted; no doubt many mothers have given the children extra money for ice cream after knowing its value as food for the growing child. Nevertheless, the manufacturer gets the most out of his advertising, when the appeal is to the strongest buying motive.

Of the rational buying motives, only one may be consistently appealed to, namely, dependability of quality. When an appeal is made on this basis the manufacturer stresses the purity and the uniformity of his product. Because of the nature of this motive, its greatest value is in securing the consumers' confidence in the product. The consumer is more apt to do without ice cream than to go far out of his way to secure it, if he is actuated only by dependability of quality. Rational buying motives have a greater influence on the retailer than emotional ones; hence, from this point of view, dependability in quality may well be stressed.

The modern tendency in the ice cream industry seems to be toward a larger scale of production. This is made possible by the increasing part that machinery plays in the manufacture of ice cream and the substantial backing the industry is receiving from large capital. As the scale of production grows larger, the formulation of the internal operating policies grows more complicated. The yearly marketing of several million gallons of ice cream by a single plant necessitates a highly efficient

selling organization. Such an organization may be divided into a sales department, which deals with the problems of handling and paying salesmen; an advertising department; and a delivery department, which should rightly come under the sales manager. Perfect coördination in selling, advertising, and delivery is essential to sound merchandising.

Many books have been written covering the organization and handling of sales departments. The various steps outlined above are taken up in great detail and must necessarily be outside the scope of this text. Furthermore, the problems confronting the various ice cream manufacturers in this respect are so varied that in most cases they must be worked out individually for each organization. With the introduction of the iceless cabinet, for instance, the manufacturer had to decide upon a new policy. Should he continue to furnish iceless cabinets to dealers following the long-established practice of furnishing salt-and-ice cabinets, or should the retailer furnish his own cabinet and be granted a price differential? Conditions in each section are such that the individual manufacturer should work out his own policy.

**The physical handling** of ice cream is a problem that deserves more attention. The rate of stock turn is as important to the ice cream manufacturer as to any type of retail merchant. Carrying stocks of ice cream at around 0° F. is costly under any circumstances; when an excessive stock is carried, the carrying cost becomes too large. The rate of stock turn is slowed up by the smaller-sized cans filled with less popular flavors. One large firm on the Pacific Coast is making a decided success of handling 5-gal. packages only. They reason that the customer who cannot handle at least 5 gals. at a time makes an unprofitable stop for the truck. Furthermore, stock control with cans of only one size is greatly simplified. Undoubtedly, a firm employing such a policy loses a few sales. But even so, the profit from such sales will hardly cover the cost of carrying in stock a large variety of flavors in cans of many sizes.

**Price Policy.**—The demand for ice cream may be generally considered inelastic; that is, slight reductions in price do not materially increase consumption. Some cities have been the scene of foolish price wars among manufacturers, when drastic price cutting, both to the retailer and the consumer, affected only slightly the total consumption. It is quite evident that the manufacturer is faced with a task much broader than selling ice cream; his task is one of aggressive merchandising in its broader sense. He must stimulate latent buying motives in the consumer. The purchaser must be awakened to his wants so that at a particular price he will consume more ice cream.

It is a well-known principle of economics that a manufacturer should

sell his product at a price that will cover the cost of production and allow a fair profit. The price of ice cream, however, cannot be arbitrarily determined, because it is generally well established in each section by competitive conditions. As a matter of fact, there is a surprisingly small range in the wholesale price of ice cream as it is quoted throughout the United States. Most manufacturers ostensibly adhere to a one-price policy. Price differential or price cutting to the retailer usually takes the form of so-called dealer help; that is, the manufacturer will agree to furnish the dealer with an electric sign, an awning, or an iceless cabinet. There is no doubt that such practices are greatly abused. The manufacturer furnishes a dealer with an iceless cabinet which he uses for several months or a season. Along comes a representative from a competitor offering to install a new cabinet and perhaps to give the dealer an electric sign. The dealer, in most cases, having everything to gain and nothing to lose, allows the new cabinet to go in. When the truck of the first manufacturer calls the next day, he finds his cabinet on the sidewalk and a new sign displayed over the store. Such is the inevitable result of substituting price concessions for good merchandising. It takes courage and foresight to maintain a one-price policy in the face of such competition; but just so soon as a manufacturer shifts his selling effort from price to dependability in quality, then will the reputation of the firm for integrity and the quality of the product reach the point where price concessions are not necessary.

A uniform quantity discount, however, might well be worked out and applied to ice cream merchandising. Such a policy has been successfully used by the National Biscuit Company for a number of years. Their customers, as respects quantity discounts, are divided into four classes:

Class A includes those customers who buy a total of all our biscuit amounting to $200 or more in a given month. These customers receive a discount of 15 per cent.

Class B includes customers who buy $50 or more in a given month but less than $200. These receive a discount of 10 per cent.

Class C includes customers who purchase $15 or more in a given month but less than $50. These customers receive a 5 per cent discount.

Class D include those customers who purchase less than $15 of all our biscuit in a given month, and who receive no quantity discount.[2]

The National Biscuit Company makes the following claim:

Under this plan many independent retailers formerly in Class B or C have now by energy and alert business methods and genuine salesmanship built up their businesses to $200 or more per month, thus putting

[2] Statement published by National Biscuit Company, September 9, 1922, regarding complaint of the Federal Trade Commission.

themselves in Class A and obtaining the largest discount that anyone can obtain from the National Biscuit Company.

Inasmuch as the wholesale price of ice cream tends to be apparently uniform in each market at any one time, the manufacturer who through efficiency can keep production costs below the average of his competitors without sacrificing quality is fortunate indeed. Since costs of raw

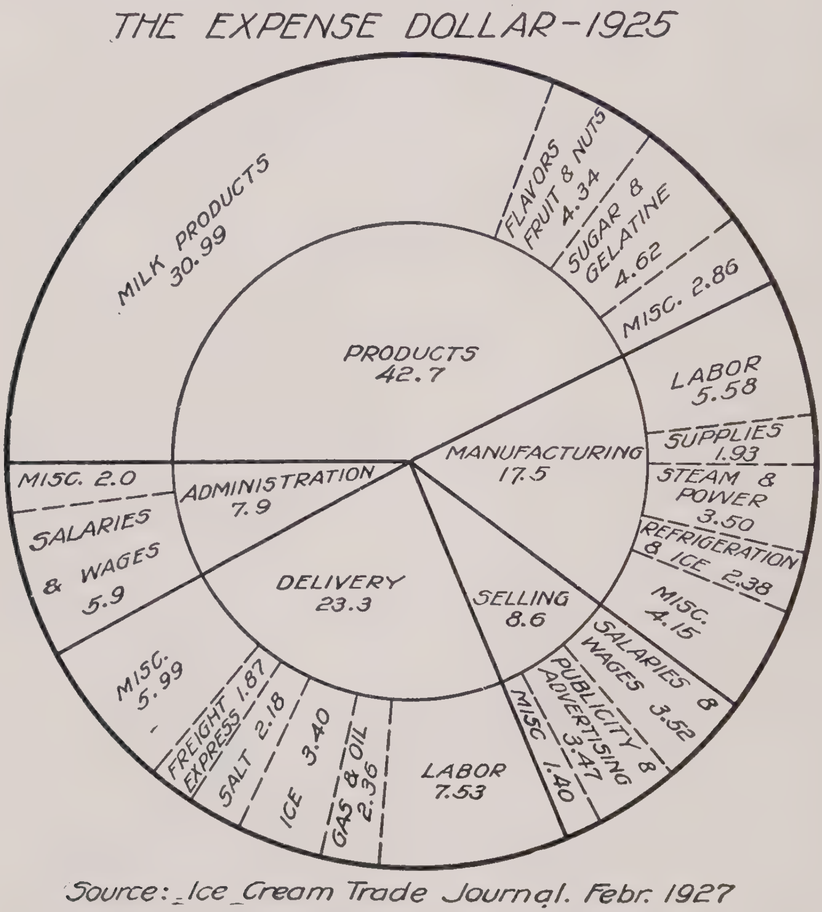


Fig. 106.

materials and wholesale selling prices tend to be uniform, his margin or gross profit should be greater. Such additional margin can be used to build more business through advertising and to provide a surplus against a time of depression or price war, which every sound business man should anticipate.

# INDEX

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